INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

28073

1857.

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INDEX.

PAGE

Annual Report 1

Agricultural Purposes, Application of Steam Power to, by W. Waller

III. Field Implements 41

Blowing Engine and Rolling Mill at Dowlais Ironworks, by W. Menelaus . 112

Boiler, Upright Steam, by T. Dunn 130

Charcoal and Coke, Manufacture of, by E. Rogers 25

Cranes, Tubular Wrought Iron, by W. Fairbairn 87

Decimal Measure of Length, Standard, by J. Whitworth, President . . 134

Ditto ditto ditto continued discussion 227

Evaporating Power, Relative, of Brass and Iron Tubes, by G. Tosh . . 119

Feed Pipe Connexion, for Locomotive Engines and Tenders, by J. Fenton . 99

Fuel Economiser, E. Green's, by W. G. Craig 196

Furnace, Regenerative, by C. W. Siemens 103

Gas, Lighting Railway Trains with, T. J. Thompson's System of, by J. Kitson 242

Hydraulic Engine, by D. Joy 184

Pile Driver, Steam, and Theory of Pile Driving, by M. Scott and A. J. Robertson 12

Pressure Gauge, by J. Inshaw 204

Railway Carriages, Saving of Dead Weight in, by C. Fay 149

Safety Escape Pipe for Steam Boilers, W. Routledge's, by J. Ramsbottom . 179

Safety Valves for Steam Boilers, by J. C. Kay 211

Smoke Prevention Apparatus, by W. B. Johnson 125

Spring, Convex-Plate Laminated, by J. Wilson 219

Steam Cultivation, by J. Fowler, Jun. 57

Steam Hammer, W. Naylor's Double-Acting, by C. Markham . . . 233

Steel Manufacture, Improvements in, by T. W. Dodds 162

Subjects for Papers 5

Valves, R. Wilson's Balanced Steam, by C. Beyer 189

Ventilating Apparatus for Buildings, &c., C. Watson's, by S. Thornton . 259

Water Meter, Chadwick and Frost's Piston, by B. Fothergill . . . 172

Wood Shaping Machinery, by J. W. Wilson 77

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1857.

1848. Adams, William Alexander, Midland Works, Birmingham.
1851. Addison, John, 3 Delahay Street, Westminster, S.W.
1853. Adkins, Francis, Heath Lead Works, near Birmingham.
1847. Allan, Alexander, Locomotive Superintendent, Scottish Central Railway, Perth.
1856. Allen, Edward Ellis, 37 Brompton Row, London, S.W.
1856. Allen, James, Cambridge Street Works, Manchester.
1856. Anderson, John, Chief Inspector of Machinery, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Messrs. Courtney and Stephens, Blackall Place Iron Works, Dublin.
1857. Armstrong, Joseph, Great Western Railway, Northern Division, Locomotive Department, Wolverhampton.
1857. Ashbury, James Lloyd, Railway Carriage and Wheel Manufactory, Openshaw, near Manchester.
1848. Ashbury, John, Railway Carriage and Wheel Manufactory, Openshaw, near Manchester.

1848. Bagnall, William, Gold's Hill Iron Works, Westbromwich.
1848. Baker, William, London and North Western Railway, Euston Station, London, N.W.
1847. Barwell, William Harrison, Eagle Foundry, Northampton.
1851. Beasley, Joseph, District Iron Works, Smethwick.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1854. Bennett, Peter Duckworth, Spon Lane Iron Works, Westbromwich.
1847. Beyer, Charles, Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, Manor House Works, Long Eaton, near Derby.
1851. Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.
1847. Bovill, George Hinton, Messrs. Swayne and Bovill, 19 Abchurch Lane, London, E.C.
1854. Bragge, William, Engineer, Gas Works, Buenos Ayres: (or care of Joseph Bragge, 123 Vyse Street, Birmingham.)

1854. Bramwell, Frederick Joseph, 29 New Bridge Street, Blackfriars, London, E.C.
1856. Bray, Edwin, New Dock Iron Works, Leeds.
1848. Broad, Robert, Horseley Iron Works, near Tipton.
1852. Brogden, Henry, Ulverstone, Cumberland.
1847. Brown, James, Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1850. Brown, John, Atlas Steel Works, Sheffield.
1855. Brown, John, Mining Engineer, Barnsley, Yorkshire.
1856. Brown, John, Mining Engineer, Bank Top, Darlington.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1856. Bunning, Theophilus Wood, Ouseburn Engine Works, Newcastle-on-Tyne.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Midland Great Western Railway, Dublin.
1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel Works, Sheffield.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1849. Chamberlain, Humphrey, Clerkenleap, Kempsey, near Worcester.
1852. Chellingworth, Thomas T., Sydenham Works, Westbromwich.
1857. Chrimes, Richard, Messrs. Guest and Chrimes, Brass Works, Rotherham.
1854. Clark, Daniel Kinnear, 11 Adam Street, Adelphi, London, W.C.
1847. Clift, John Edward, Engineer, Birmingham and Staffordshire Gas Works, Adderley Street, Birmingham.
1847. Cochrane, Alexander Brodie, Woodside Iron Works, near Dudley.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1847. Coke, Richard George, Ankerbold, near Chesterfield.
1853. Cooper, Samuel Thomas, Hanover Square, Leeds.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, Great Northern Railway, Locomotive Department, Doncaster.
1849. Cowper, Charles, 20 Southampton Buildings, Chancery Lane, London, W.C.
1847. Cowper, Edward Alfred, 35A Great George Street, Westminster, S.W.
1853. Craig, William G., Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.
1847. Crampton, Thomas Russell, 15 Buckingham Street, Adelphi, London, W.C.
1857. Criswick, Theophilus, Plymouth Iron Works, Merthyr Tydvil.
1848. Croome, John, New Cross, London, S.E.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
1857. Deane, John Horridge, Barcelona and Granollers Railway, Locomotive Department, Barcelona: (or care of Edward G. Deane, Solicitor, Liverpool.)
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1854. Dodds, Thomas W., Holmes Engine Works, Rotherham.

1857. Douglas, George, Resident Engineer, Birkenhead Lancashire and Cheshire Junction Railway, Birkenhead.
1857. Dove, George, Woodbank Iron Works, Carlisle.
1847. Dubs, Henry, 9 Richmond Grove, Longsight, near Manchester.
1856. Dudgeon, John, 151 Fenchurch Street, London, E.C.
1856. Dudgeon, William, 151 Fenchurch Street, London, E.C.
1857. Dunlop, John Macmillan, Marlborough Street, Oxford Street, Manchester.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.

1856. Eastwood, James, Railway Iron Works, Derby.
1848. Elder, David, Vulcan Foundry, Glasgow.
1849. Elwell, Edward, Jun., Wednesbury Forge, Wednesbury.
1853. England, George, Hatcham Iron Works, New Cross, Surrey, S.E.
1857. Evans, John Campbell, Morden Iron Works, East Greenwich, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Bordesley, Birmingham.

1847. Fairbairn, William, F.R.S., The Polygon, Ardwick, Manchester.
1852. Fairbairn, Thomas, Canal Street Works, Manchester.
1849. Fairbairn, William A., Canal Street Works, Manchester.
1857. Fairlie, Robert Francis, 10 Liverpool Street, New Broad Street, London, E.C.
1856. Fay, Charles, Lancashire and Yorkshire Railway, Carriage Department, Manchester.
1847. Fenton, James, Low Moor Iron Works, near Bradford, Yorkshire.
1854. Fernie, John, Midland Railway, Locomotive Department, Derby.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.
1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1849. Forsyth, Thomas, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1847. Fothergill, Benjamin, 16 Queen's Chambers, 5 Market Street, Manchester.
1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1857. Fowler, John, Jun., 28 Cornhill, London, E.C.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1853. Fraser, Joseph Boyes, Alma Place, Kenilworth.
1856. Freeman, Joseph, 22 Cannon Street, London, E.C.
1852. Froude, William, Dartington, Totnes, Devonshire.

1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1856. Gilkes, Edgar, Tees Engine Works, Middlesboro'-on-Tees.
1854. Goode, Benjamin W., St. Paul's Square, Birmingham.
1847. Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.

1852. Gordon, Robert, Heaton Foundry, Stockport.
1848. Green, Charles, Tube Works, Loek Street, Birmingham.
1857. Gregory, John, Engineer, Portuguese National Railway South of Tagus, Barriero, near Lisbon: (or care of Hugh Greaves, 5 Victoria Street, Westminster, S.W.)

1857. Hall, William, Bloomfield Iron Works, Tipton.
1856. Harrison, George, Canada Works, Birkenhead.
1848. Hartree, William, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1857. Haughton, S. Wilfred, Locomotive Superintendent, Dublin and Wicklow Railway, Dublin.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1853. Headly, James J., Eagle Works. Cambridge.
1857. Healey, Edward Charles, 32 Bucklersbury, London, E.C.
1847. Henderson, John, Smethwick, near Birmingham.
1847. Hennet, George, 24 Duke Street, Westminster, S.W.
1850. Henson, Henry H., 38 Parliament Street, Westminster, S.W.
1848. Hewitson, William Watson, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1854. Hodgkin, John Eliot, Suffolk Works, Berkeley Street, Birmingham.
1852. Holcroft, James, Shut End. Brierley Hill, Worcestershire.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1856. Hopkinson, John, Messrs. Wren and Hopkinson, Altrincham Street, Manchester.
1851. Horton, Joshua, Etna Works, Smethwick.
1847. Howell, Joseph, Hawarden Iron Works, Holywell, Flintshire.
1857. Humber, William, Pancras Chambers, Pancras Lane, Bucklersbury, London, E.C.
1856. Hunt, Thomas, London and North Western Railway, Locomotive Department, Crewe.

1850. Ikin, Jonathan Dickson, 2 Cannon Row, Westminster, S.W.
1857. Inshaw, John, Engine Works, Morville Street, Birmingham.

1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1856. James, Jabez, 28A Broadwall, Stamford Street, Lambeth, London, S.
1848. Jee, Alfred Stanistreet, 6 John Street, Adelphi, London, W.C.
1855. Jeffcock, Parkin, Mining Engineer, 3 Stuart Terrace, Greenhill, Derby.
1856. Jeffreys, Edward, Locomotive Superintendent, Shrewsbury and Hereford Railway, Shrewsbury.
1857. Jenkins, William, Locomotive Superintendent, Lancashire and Yorkshire Railway, Miles Platting, Manchester.

1854. Jobson, John, Derwent Foundry, Derby.
1847. Jobson, Robert, Wordsley Works, near Stourbridge.
1847. Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
1848. Johnson, Richard William, The Laurels, Hagley Road, Birmingham.
1849. Johnson, William, 166 Buchanan Street, Glasgow.
1855. Johnson, William Beckett, St. George's Iron Works, Hulme, Manchester.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1857. Jones, John Hodgson, 1 Poet's Corner, Westminster, S.W.
1853. Joy, David, 5 Queen Square, Leeds.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near North Shields.
1847. Kennedy, James, 59 Erskine Street, Liverpool.
1857. Kennedy, Lieut.-Col. John Pitt, R.E., Engineer, Bombay Baroda and Central Indian Railway, 10 Liverpool Street, New Broad Street, London, E.C.
1848. Kinmond, William L., Hamilton Steam Engine and Forge Works, Hamilton, Canada West.
1848. Kirkham, John, 109 Euston Road, London, N.W.
1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.
1848. Kitson, James, Airedale Foundry, Leeds.

1857. Laybourn, John, Isca Foundry, Old Barracks Works, Newport, Monmouthshire.
1856. Laybourn. Richard, Locomotive Superintendent, Monmouthshire Railway and Canal Company, Newport, Monmouthshire.
1857. Lees, John, Park Bridge Iron Works, Ashton-under-Lyne.
1857. Lees, Sylvester, Locomotive Superintendent, East Lancashire Railway, Bury, Lancashire.
1856. Levick, Frederick, Cwm Celyn Blaina and Coalbrook Vale Iron Works, near Newport. Monmouthshire.
1848. Lewis, Benjamin, Stanley Street Works, Salford, Manchester.
1856. Linn, Alexander Grainger, 121 Upper Parliament Street, Liverpool.
1857. Little. Charles, Midland Railway, Locomotive Department, Derby.
1854. Lloyd, George Braithwaite, Tube Works, Gas Street, Birmingham.
1847. Lloyd. Sampson, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.
1856. Longridge, Robert Bewick, 11 Winfield Terrace, Old Trafford, Manchester.
1854. Lynde, James Gascoigne, Town Hall, Manchester.

1848. MacGregor, Walter F., Vauxhall Foundry, Liverpool.
1856. Mackay, John, Drogheda Iron Works, Drogheda.
1857. March, George, Union Foundry, Leeds.

1856. Markham, Charles, Midland Railway, Derby.
1848. Marshall, Edwin, Britannia Carriage Works, Birmingham.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1853. Marten, Henry, 19 Darlington Street, Wolverhampton.
1857. Martindale. Capt. Benjamin Hay, R.E., Superintendent of Railway and Civil Works, Melbourne, Victoria.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1857. Masselin, Armand, Spon Lane Glass Works, near Westbromwich.
1853. Matbews, William, Corbyn's Hall Iron Works, near Dudley.
1848. Matthew, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1857. May, Walter, 3 Great George Street, Westminster, S.W.
1847. McClean, John Robinson, 17 Great George Street, Westminster, S.W.
1847. McConnell, James Edward, Locomotive Superintendent, London and North Western Railway, Wolverton.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1857. Metford, William Ellis, East Indian Railway, Monghyr, India: (or care of William Metford, Flook House, Taunton.)
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1853. Miller, George Mackey, Great Southern and Western Railway, Dublin.
1847. Miller, Joseph, F.R.S., Oakley House, Alpha Road, St. John's Wood, London, N.W.
1856. Mitchell, Charles, Low Walker Iron Ship Building Works, Newcastle-on-Tyne.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1857. Mowbray, Frederick William, Queen's Gate, Bradford, Yorkshire.
1857. Muntz, George Frederick, French Walls, near Birmingham.
1856. Muntz, George Henri Marc, 3 Lansdowne Terrace, Handsworth, near Birmingham.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, Vulcan Foundry, Glasgow.
1856. Newall James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1851. Nixon, Charles, 26 Great George Street, Westminster, S.W.
1850. Norris, Richard Stuart, London and North Western Railway, Engineer's Office, Liverpool.

1847. Owen, William, Messrs. Sandford and Owen, Phœnix Works, Rotherham.

1847. Paton, William, Locomotive Superintendent, Edinburgh and Glasgow Railway, Cowlairs, Glasgow.
1853. Payne, Edward J., 1 Bennett's Hill, Birmingham.
1847. Peacock, Richard, Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1848. Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
1848. Penn, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.

1856. Perring, John Shae, Resident Engineer, East Lancashire Railway, Bury, Lancashire.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., St. Helen's Foundry, St. Helen's.
1852. Plant, Reuben, Pensnett Collieries, Brierley Hill, Worcestershire.
1856. Pollard, John, Machine and Tool Maker, Leeds.
1852. Porter, John Henderson, Iron Roofing Works, Gas Street, Birmingham.
1856. Preston, Francis, Ardwick Spindle Works, Manchester.
1848. Preston, Robert B., 10 Abercromby Square, Liverpool.
1855. Prideaux, Thomas Symes, 32 Charing Cross, London, S.W.

1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.
1856. Reeves, Charles, Toledo Works, Charlotte Street, Birmingham.
1857. Rennie, George, 21 Whitehall Place, Westminster, S.W.
1856. Richards, Josiah, Ebbw Vale Iron Works, near Newport, Monmouthshire.
1847. Richards, Thomas, 30 Hill Morton Road, Rugby.
1848. Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
1847. Robinson, Henry, 8 Chandos Street, Cavendish Square, London, W.
1847. Roche, David M., East Indian Railway, Howrah, Calcutta.
1852. Rofe, Henry, Engineer, Birmingham Water Works, Paradise Street, Birmingham.
1851. Rogers, Ebenezer, Abercarn, near Newport, Monmouthshire.
1853. Rogers, Jonathan, Pontypool Iron Works, near Newport, Monmouthshire.
1851. Rolinson, Thomas, Wellington Road, Dudley.
1853. Ronayne, Joseph P., Engineer-in-Chief, Sierra Nevada Lake Water and Mining Company, (Post Office, San Francisco,) California: (or care of T. Mahony, 3 Camden Quay, Cork.)
1853. Ross, John, Messrs. Brown Marshalls and Co., Britannia Carriage Works, Birmingham.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Leeds.
1857. Routledge, William, New Bridge Foundry, Salford, Manchester.
1856. Russel, Robert, Resident Engineer, Manchester, Sheffield and Lincolnshire Railway, Manchester.
1847. Russell, John Scott, F.R.S., 37 Great George Street, Westminster, S.W.

1848. Samuel, James, 26 Great George Street, Westminster, S.W.
1857. Samuelson, Alexander, Scott Street Foundry, Hull.
1857. Samuelson, Martin, Scott Street Foundry, Hull.
1848. Scott, Michael, 26 Great George Street, Westminster, S.W.
1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.
1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.
1856. Shelley, Charles Percy Bysshe, 21 Parliament Street, Westminster, S.W.
1851. Siemens, Charles William, 7 John Street, Adelphi, London, W.C.

1847. Sinclair, Robert, Locomotive Superintendent, Eastern Counties Railway, Stratford, London, E.
1857. Sinclair, Robert Cooper, Temple Buildings, Birmingham.
1853. Slaughter, Edward, Avonside Iron Works, Bristol.
1854. Smith, George, Wellington Road, Dudley.
1847. Smith, Henry, Spring Hill Works, Birmingham.
1857. Smith, Josiah Timmis, Windmill End Furnaces, Dudley.
1857. Smith, William, 10 Salisbury Street, Adelphi, London, W.C.
1857. Snowdon, Thomas, Tees Side Iron Works, Middlesboro'-on-Tees.
1853. Spencer, Thomas, Oaken, Wolverhampton.
1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1857. Spray, Frederic George, St. Petersburgh: (or care of Edward Corry, 8 New Broad Street, London, E.C.)
1855. Stenson, William, Jun., Whitwick Collieries, near Ashby-de-la-Zouch.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.
1857. Stokes, Lingard, Locomotive Superintendent, East Indian Railway, Howrah, Calcutta.

1848. Thompson, Isaac, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1851. Thompson, James, Pin Mill, Ardwick, Manchester.
1857. Thompson, John Taylor, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1857. Thompson, Robert, Haigh Foundry, near Wigan.
1852. Thomson, George, Crookhay Furnaces, Westbromwich.
1848. Thornton, Robert, 54 North Bridge, Edinburgh.
1847. Thornton, Samuel, Bradford Street, Birmingham.
1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.
1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.
1856. Truss, Thomas, Shrewsbury and Chester Railway, Carriage Department, Chester.
1849. Turton, Thomas Burdett, Sheaf Works, Sheffield.
1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1856. Waddington, John, New Dock Iron Works, Leeds.
1856. Waddington, Thomas, New Dock Iron Works, Leeds.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1856. Waller, William, Messrs. John Gray and Co., Uddingston, near Glasgow.
1856. Wardle, Charles Wetherell, Railway Foundry, Leeds.

1852. Warham, John R., Iron Works, Burton-on-Trent.
1847. Weallens, William, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1857. West. Frank W. S., East Indian Railway, Calcutta.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1856. Whitehouse, Henry Bickerton, Deepfields Iron Works, near Bilston.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1847. Williams, Richard, Patent Shaft Works, Wednesbury.
1850. Williams, Walter, Jun., Albion Iron Works, Westbromwich.
1856. Wilson, Edward, Oxford Worcester and Wolverhampton Railway, Worcester.
1857. Wilson, John, Spring Works, Hill Top, Westbromwich.
1852. Wilson, Joseph W., Seymour Chambers, Duke Street, Adelphi, London, W.C.
1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.
1848. Wingate, Thomas, Whiteinch Foundry, Partick, near Glasgow.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Midland Road, Derby.
1848. Wright, Henry, Saltley Works, Birmingham.
1848. Wright, Joseph, Saltley Works, Birmingham.
1853. Wymer, Francis W., 5 Heaton Terrace, Elwick's Lane, Newcastle-on-Tyne.

1856. Yarrow, Thomas, Locomotive Superintendent, Scottish North Eastern Railway, Arbroath.
1856. Young, John, Railway Foundry, Leeds.

LIFE MEMBERS.

1853. Maudslay, Henry, 4 Cheltenham Place, Lambeth, London, S.
1847. Stephenson, Robert, M.P., 24 Great George Street, Westminster, S.W.

HONORARY MEMBERS.

1848. Branson, George, Belmont Row, Birmingham.
1851. Clare, Thomas Deykin, Midland Railway Station, Birmingham.
1848. Crosby, Samuel, Leek Street, Birmingham.
1850. Gwyther, Edwin, Belmont Row, Birmingham.
1857. Hawkes, William, Eagle Foundry, Broad Street, Birmingham.
1854. Knight, George, 22 Parliament Street, Westminster, S.W.
1856. Marshall, John, Low Moor Iron Works, near Bradford, Yorkshire.
1856. Moss, Henry E., 2 Rumford Place, Liverpool.
1848. Peto, Sir Samuel Morton, Bart., 9 Great George Street, Westminster, S.W.
1856. Pettifor, Joseph, Midland Railway, Derby.
1856. Singleton, William, Dock Street, Leeds.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1854. Woolley, Rev. Joseph, LL.D., Royal Dockyard, Portsmouth.

HONORARY LIFE MEMBERS.

1849. Hodgkinson, Eaton, F.R.S., 44 Drayton Grove, Brompton, London, S.W.
1848. MacGregor, James, 25 Eccleston Square, London, S.W.

GRADUATES.

1850. Glydon, George, Spring Hill Works, Eyre Street, Birmingham.
1851. Potts, J. Thorpe, Tube Works, Nile Street, Birmingham.

PROCEEDINGS.

January 28, 1857.

The Tenth Annual General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 28th January, 1857; Joseph Whitworth, Esq., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1857.

The Council have the pleasure, on this occasion of the Tenth Anniversary of the Institution, of congratulating the Members on the satisfactory position and successful progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1856, shows a balance in the Treasurer's hands of £298 5*s.* 9*d.*, after the payment of all accounts due to that date. The Finance Committee have examined and checked all the receipts and payments of the Institution for the last year, 1856, and report that the following Balance Sheet rendered by the Treasurer is correct.

(*See Balance Sheet appended.*)

The Council report with satisfaction the important increase in the number of Members that has taken place during the last year. The total number of Members of all clases for the year is 259, of whom 17 are Honorary Members and 3 are Graduates.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year :—

Engineering Lectures at the "Ecole Impériale des Ponts et Chaussées" of France, presented by M. Cavalier, Director :—
Mineralogy, applied to Building, by M. Dufrénoy.
Construction of Roads (second part)—Construction and Maintenance.
Administrative Law, by M. Cotelle.
Inland Navigation, by M. Mary.
Catalogue of English and American Works in the Library of the Ecole Impériale.
Engravings and Description of the Machinery of the "Arabia" and "La Plata," by Mr. David Kirkaldy, from the Author.
Description and Engravings of Glenelg Pier and L'Ouvred Breakwater, from the Uskside Iron Company.
Essay on the Cleansing of Coal, by M. Aristide Bérard, from the Author.
Memoirs of the Manchester Literary and Philosophical Society, Vol. XIII.
Transactions of the Royal Scottish Society of Arts.
Transactions of the Liverpool Polytechnic Society.
Abstract Minutes of Proceedings of the Institution of Civil Engineers.
Journal of the Society of Arts.
The Artizan Journal, from the Editor.
The Civil Engineer and Architect's Journal, from the Editor.
The London Journal of Arts, from the Editor.
The Mechanics' Magazine, from the Editor.
The Engineer, from the Editor.
The Mining Journal, from the Editor.
The Practical Mechanics' Journal, from the Editor.
The Railway Record, from the Editor.
Model of a Double Slide Expansion Valve for Marine Engines, from Mr. Francis W. Wymer.
Model of a Straight Link Motion for Locomotive Engines, from Mr. Alexander Allan.
Specimens of Machine-made Cotter-holes with Drills, from Mr. Thomas Forsyth.
Specimens of Steel, from Mr. Charles Cammell.
Specimen of Machine Rivetting, from Mr. Robert Harvey.
Model of Framing of an Iron Construction of Foundry, from Mr. John Downie.

The Council have great satisfaction in referring to the large number of papers that have been read at the Meetings of the Institution during the year, and the practical interest and value of many of the communications, which form an important addition to the Proceedings of the Institution. The Council call the special attention of the Members to the importance of their aid and co-operation in carrying out the objects of the Institution and

maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members. The Council invite communications from the Members and their friends upon the subjects in the list appended, and other subjects advantageous to the Institution; also contributions to the Library and to the collection of Mechanical Models and Drawings.

The following Papers have been read at the Meetings during the last year:—

Address of the President, Joseph Whitworth, Esq.

Description of the Pumping Engines of the Wolverhampton Water Works, with some remarks on Water Pumping; by Mr. Henry Marten, of Wolverhampton.

On Wood Bearings for Screw Propeller Shafts; by Mr. John Penn, of London.

Description of an improved construction of Crossing; by Mr. Henry Woodhouse, of Stafford.

On an improved Safety Valve; by Mr. John Ramsbottom, of Manchester.

Description of an improved Foundry Hoist and Cupola; by Mr. John Fernie, of Derby.

Description of a Double Slide Expansion Valve for Marine Engines; by Mr. Francis W. Wymer, of Newcastle-on-Tyne.

On Waddell's improved Packing for the Slide Valves of Marine Engines; by Mr. Charles Beyer, of Manchester.

On an improved construction of Link Motion for Locomotive and other Engines; by Mr. Alexander Allan, of Perth.

On the Application of Steam Power to Agricultural Purposes; by Mr. William Waller, of Lincoln.

Description of a Double Traversing Drilling and Grooving Machine; by Mr. Thomas Forsyth, of Manchester.

On an improved Water Meter; by Mr. C. William Siemens, of London.

Description of an improved Steam Rivetting, Punching, and Shearing Machine; by Mr. Robert Harvey, of Glasgow.

Description of improved Corn Mill Machinery; by Mr. Alexander White, of Partick.

Description of a Compressed Air Engine at Govan Colliery; by Mr. Charles Randolph, of Glasgow.

Description of an improved Water Meter; by Mr. Thomas Kennedy, of Kilmarnock.

Description of a Direct-Action Marine Engine for Screw Propulsion; by Mr. Edmund Hunt, of Glasgow.

Description of an Iron Construction of Foundry, and an improved process of Moulding Pipes and Hollow Cast Ware; by Mr. John Downie, of Glasgow.

Description of a Central Buffing and Drawing Apparatus for Railway Carriages; by Mr. E. D. Chattaway, of Edinburgh.

Description of an improved Sugar Evaporating Apparatus; by Mr. Robert Harvey, of Glasgow.

On a Surface Condenser; by Mr. James P. Joule, of Manchester.

Description of Boucherie's Process for the Preservation of Timber; by Mr. John Reid, Jun., of Glasgow.

On Grooved-Surface Frictional Gearing; by Mr. James Robertson, of Ardrossan.

Description of a Steam Boiler with combined Internal and External Furnaces; by Mr. John Stephen, of Glasgow.

Description of an improved Ladder for Dredging Machines; by Mr. Michael Scott, of Blyth.

On a new construction of Iron Ships for War Purposes; by M. Pietro Conti, Commissioner of the Sardinian Government.

Description of a new Machine for Cutting and Forging Files; by Mr. Robert C. Ross, of Glasgow.

Description of an improved Steam Boiler for Locomotive and other Engines; by Mr. Alexander Allan, of Perth.

On an improved Locomotive Boiler; by Mr. Walter Neilson, of Glasgow.

Description of a Steam Dash Wheel for Bleaching; by Mr. James Wallace, Jun., of Glasgow.

Description of an improved Water Meter; by Mr. William Gorman, of Glasgow.

Description of the Ventilating Fan at the Abercarn Collieries; by Mr. Ebenezer Rogers, of Abercarn.

On the Application of Steam Power to Agricultural Purposes (second paper); by Mr. William Waller, of Lincoln.

Description of an improved Steam Pile Driver; by Mr. Robert Morrison, of Newcastle-on-Tyne.

The Council have particular pleasure in recording the eminently successful meeting of the Institution held in Glasgow in the autumn of last year, and in expressing their sense of the very spirited and hospitable reception that was given to the Members of the Institution on that occasion by their northern friends. They consider this meeting may be looked upon as the commencement of a more intimate communication and intercourse amongst mechanical men; and feel confident it will result in important advantages to the Institution by extending its efficiency, leading to a freer interchange of mechanical ideas and experience, and confirming the fact that the day of secrets in the workshop is gone by. The Council anticipate many other occasions of holding similar meetings, both there and in other districts of the country.

It is intended to hold a Meeting of the Institution in Manchester in the present summer, during the time of the Exhibition of Art Treasures, when an important and interesting Meeting is anticipated.

The President, Vice-Presidents, and Officers of the Institution, and five of the Members of the Council in rotation, will go out of office this day, according to the Rules of the Institution; and the ballot will be taken at the present Annual Meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

Steam Engine Boilers, particulars of construction—form of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working.

Steam Engines, expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—governors—valves, bearings, &c.—indicator figures from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator figures for reference in the Institution.

Pumping Engines, particulars of various constructions—size of cylinder and degree of expansion—strokes per minute, and horse power—number and size of pumps, and strokes per minute—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

Blast Engines, best kind of engine—size of cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

Marine Engines, power of engines in proportion to tonnage—different constructions of engines—dynamical effect compared with indicator figures—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse power applied, speed obtained, section of vessel—iron and wood ships, details of construction, lines, tonnage, cost, &c.

Rotary Engines, particulars of construction and practical application—details of results of working.

Locomotive Engines, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—consumption of fuel—use of coal—consumption of smoke—heating surface, length and diameter of tubes—experiments on size of tubes and blast pipe—expenses of working and repairing—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams.

Agricultural Engines, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural purposes.

Caloric Engines—engines worked by Gas, Gun-cotton, or other explosive compounds—Electro-magnetic engines—particulars and results.

Water-Wheels, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, per-centage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

Wind Mills, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

Corn Mills, particulars of improvements—power employed—application of steam power—results of working with an air blast and small stones—advantages of regularity of motion.

Sugar Mills, particulars of construction and working—results of the application of the hydraulic press in place of rolls—construction and working of evaporating pans.

Saw Mills, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

Oil Mills, facts relating to the construction and working, by stampers and by pressure.

Cotton Mills, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

Machinery for manufacturing Flax, both in the natural length of staple and when cut.

Rolling Mills, improvements in machinery for making iron and steel—mode of applying power—steam hammers—piling of iron—plates—fancy sections—arrangement of rolls.

Stamping and Coining Machinery, particulars of improvements, &c.

Paper-Making and Paper-Cutting Machines, ditto ditto

Printing Machines, ditto ditto

Calico-Printing and Bleaching Machinery, ditto ditto

Water Pumps, facts relating to the best construction, means of working, and application—best forms—velocity of piston—construction of valves.

Air Pumps, ditto ditto ditto

Hydraulic Presses, facts relating to the best construction, means of working, and application.

Rotary and Centrifugal Pumps, ditto ditto ditto

Fire Engines, ditto ditto ditto

Sluices and Sluice Cocks, ditto ditto ditto

Cranes, ditto ditto ditto

Steam Cranes, Hydraulic Cranes, Pneumatic Cranes, ditto

Lifts for raising Trucks, &c. ditto ditto ditto

Lathes, Planing, Boring, and Slotting Machines, &c., particulars of improvements—description of new self-acting tools.

Wood-working Machines, morticing, planing, &c.

Toothed Wheels, best construction and form of teeth—results of working—power transmitted—method of moulding.

Driving Belts and Straps, best make and material, leather, gutta percha, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained.

Dynamometers, construction and results of working.

Strength of Materials—facts relating to experiments on ditto, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

Durability of Timber of various kinds—best plans for seasoning timber and cordage—results of various processes—comparative durability of timber in different situations.

Corrosion of Metals by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

Alloys of Metals—facts relating to different alloys.

Friction of various Bodies—facts relating to friction under ordinary circumstances—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axle boxes, &c.—lubrication, best materials, and means of application, and results of practical trials—best plans for oil tests.

Iron Roofs, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast iron, wrought iron, timber, &c.—best construction, form, and material—details of large roofs, and cost.

Fire-proof Buildings, particulars of construction—most efficient plan—results of trials.

Chimney Stacks of large size—particulars, form, force of draught, mode of building cheapest construction, &c.

Bricks, manufacture and durability—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—machines for brick making.

Gas Works—best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, water gas, &c.—improvements in purifiers, condensers, and gas-holders—wet and dry gas-meters—pressure of gas, gas-exhauster—gas-pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

Water Works—facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—relative advantages of stand pipes and air vessels—water meters, construction and working.

Well Sinking, and Artesian Wells, facts relating to—boring tools, construction and mode of using.

Coffer Dams and Piling, facts relating to the construction.

Piers, fixed and floating, and pontoons, ditto ditto

Pile Driving Apparatus, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system.

Dredging Machines, particulars of improvements—application of dredging machines—power required and work done.

Diving Bells and Diving Dresses, facts relating to the best construction.

Lighthouses, cast iron and wrought iron, ditto ditto

Mining Operations—facts relating to mining—means of ventilating mines—use of ventilating machinery—safety lamps—mode of raising materials—safety guides—winding machinery—mode of breaking, pulverising, and sifting various descriptions of ores.

Blasting—facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder.

Blast Furnaces—consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—use of waste gases.

PUDDLING FURNACES, best forms and construction—worked with coal, charcoal, &c.

HEATING FURNACES, best construction—consumption of fuel, &c.

CONVERTING FURNACES—manufacture of steel—casehardening, &c.

SMITHS' FORGES, best construction—size and material—power of blast—hot blast, &c. —construction of tuyeres.

SMITHS' FANS, and FANS generally, best construction, form of blades, &c.—facts relating to power employed and per-centage of effect produced—pressure and quantity of air discharged—size and construction of air mains.

COKE AND CHARCOAL, particulars of the best mode of making, and construction of ovens, &c.—evaporating power of different varieties.

RAILWAYS—construction of permanent way—section of rails, and mode of manufacture —experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

SWITCHES and CROSSINGS, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

TURN-TABLES, particulars of various constructions and improvements.

SIGNALS for Stations and Trains, and self-acting signals.

BREAKS for Carriages and Wagons, best construction.

BUFFERS for Carriages, &c., and Station Buffers—different constructions and materials.

SPRINGS for Carriages, &c.—buffing, bearing, and draw springs—particulars of different constructions and materials, and results of working.

RAILWAY WHEELS, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tyres, comparative economy and results of working—solid wrought iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the paper should be on so large a scale as to be clearly visible to the meeting at the time of reading the paper, or enlarged diagrams should be sent for the illustration of any particular portions.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1856.

Cr.	£	*s.*	*d.*
By Balance 31st December, 1855	235	10	7
,, Subscriptions from 14 Members in arrear	42	0	0
,, ditto from 156 Members for 1856	468	0	0
,, ditto from 2 Graduates for 1856	4	0	0
,, ditto from 52 New Members	260	0	0
,, ditto from 1 New Graduate	3	0	0
,, ditto from 3 Members in advance for 1857	9	0	0
,, Sale of Extra Reports	23	14	0
, Interest from Bank	7	1	9
	£1052	6	4

Dr.	£	*s.*	*d.*
To Printing and Engraving Reports of Proceedings	148	17	6
,, Stationery and Printing	27	8	4
,, Office Expenses and Petty Disbursements	23	14	8
,, Expenses of Meetings	33	18	6
,, Furniture and Fittings	7	10	10
,, Travelling Expenses	20	17	8
,, Parcels	2	13	9
,, Postages	25	4	10
,, Salary	350	0	0
,, Rent and Taxes	113	14	6
,, Balance 31st December, 1856	298	5	9
	£1052	6	4

(Signed) SAMPSON LLOYD, J. E. CLIFT, } Finance Committee.

14*th January*, 1857.

The CHAIRMAN moved that the Report of the Council be received and adopted, which was passed.

The CHAIRMAN announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year :—

PRESIDENT.

JOSEPH WHITWORTH, . . .	Manchester.

VICE-PRESIDENTS.

WILLIAM FAIRBAIRN, . . .	Manchester.
JAMES FENTON, ...	Bradford.
BENJAMIN FOTHERGILL, . . .	Manchester.
HENRY MAUDSLAY, . .	London.
JAMES E. MCCONNELL, . . .	Wolverton.
JOHN RAMSBOTTOM, . . .	Manchester.

COUNCIL.

In addition to the ten Members remaining in office.

ALEXANDER ALLAN, ...	Perth.
WILLIAM G. CRAIG, . . .	Manchester.
JOHN FERNIE, ...	Derby.
C. WILLIAM SIEMENS, . . .	London.
HENRY WOODHOUSE, . . .	Stafford.

TREASURER.

HENRY EDMUNDS, ...	Birmingham.

SECRETARY.

WILLIAM P. MARSHALL, . . .	Birmingham.

The following New Members were also elected :—

MEMBERS.

JOSEPH ARMSTRONG, . . .	Wolverhampton.
GEORGE DOUGLAS, ...	Birkenhead.
JOHN CAMPBELL EVANS, . .	London.
WILLIAM HUMBER, ...	London.
JOHN LEES, ...	Ashton-under-Lyne.
CHARLES LITTLE, ...	Derby.
FREDERICK G. SPRAY, . . .	St. Petersburgh.
LINGARD STOKES, ...	Calcutta.
ROBERT THOMPSON, . . .	Wigan.
JOSEPH TOMLINSON, JUN., . . .	Derby.

The following Paper, by Mr. Michael Scott, of London, and Mr. Andrew John Robertson, of Blyth, was then read :—

ON THE THEORY OF PILE DRIVING, WITH DESCRIPTION OF AN IMPROVED STEAM PILE DRIVING MACHINE.

Theory of Pile Driving.—The subject of pile driving has been investigated by Dr. Whewell * on principles first laid down by the present Astronomer Royal; but unfortunately the mathematical expressions which contain the result are so complicated, that, although the distance a pile will be driven may be ascertained, provided the data be correct, by the substitution of numerical values in the different equations, still the process is tedious and the result unsatisfactory. For the object of such investigations is not to determine to a fraction of an inch the distance a pile will be driven, more especially as the resistance offered by the ground, which forms the most important element in the calculation, can never be accurately ascertained; but the object is to elicit those simple and general truths upon which the system depends. By supposing the pile to be only just stirred by the blow, Dr. Whewell has simplified the equations to such an extent as to deduce from them the following corollaries, which are arrived at by approximation; this approximation however holds good only when the quantities are so exceedingly small that the first two terms of a series which does not converge may be assumed to express the value of the whole series.

The deductions are—

1st. A slight increase in the hardness of the pile, or in the weight of the ram, will increase considerably the distance driven.

2nd. The resistance being great, the lighter the pile the faster it will be driven.

3rd. The distance driven varies as the cube of the weight of the ram.

Although these results cannot be depended upon as exact under all circumstances, they still give a tolerably correct indication, and are in accordance with those which may be arrived at by general reasoning. The complication in the original expressions arises from taking into consideration in the general question the weight and inertia of the pile. The weight of the pile however bears so small a proportion to the resistance of the ground that it may safely be neglected: for a 25 feet pile, 1 foot square,

* "Mechanics of Engineering."

weighs about $\frac{1}{2}$ ton; and if the fall of a ram weighing 1 ton be 10 feet, and the distance driven by the blow be 2 inches, then the resistance offered by the ground, supposing the ram and pile to be perfectly hard, will be to the weight of the ram as 120 inches to 2 inches, that is it will be 60 tons, of which $\frac{1}{2}$ ton is the $\frac{1}{120}$th part and may therefore safely be neglected. But the inertia of the pile having to be compared with that of the ram is of more importance, the proportion in the case above supposed being as 1 to 2. Although therefore the inertia of the pile be a matter of too much importance to be neglected, it may nevertheless be considered separately, to the great simplification of the question involving the compressibility of the pile and ram.

If a body at rest be impinged upon by a body in motion, the two will, if inelastic, move on together, the momentum of the whole mass after impact being the same as that of the impinging body before impact; if they be elastic, the momentum of the two bodies together is still the same, but the distribution is different. The two extremes of these conditions of things may be illustrated by a small hammer striking a pile or an anvil, and a sledge hammer striking a nail: in the first case, the hammer buries itself in the head of the pile, or rebounds from the anvil, without producing any further effect; in the second, the existence of the nail scarcely affects the motion or the blow of the sledge hammer. These two cases show at once the great advantage of mass in the striking body as compared with the mass of the body driven. In pile driving, the proportions between an ordinarily heavy hammer and a nail can never be approximated to; but we may conclude with safety that, within the limits imposed by practical considerations of convenience, and provided the material of the pile will stand the blow, the heavier the ram the more effective it will be.

Thus far the influence of mass has been considered only in overcoming the inertia of the pile; the same reasoning applies to show that the heavier the ram and consequently the greater its momentum, the greater is its power to overcome the resistance of the ground. So long as piling engines were worked by hand, any increase of weight of the ram beyond $\frac{1}{2}$ ton or $\frac{3}{4}$ ton was seldom or never thought of; and the space for the application of the power of men being very limited, the motion was necessarily very slow. The introduction of steam has removed this difficulty, and in Nasmyth's steam pile engine the weight of the ram was increased to $1\frac{1}{2}$ ton.

It remains to examine the effect of the height of fall of the ram, of which no mention has yet been made. The writers believe there has hitherto been a prevailing opinion that a rapid succession of blows from a moderately heavy ram with a short fall is more advantageous than with a high fall and proportionately diminished number of blows; for it is alleged the pile never gets leave to come to rest: this opinion however they consider to be erroneous.

Let H be the height of fall, W the weight of the ram, R the resistance of the ground, and S the space through which the pile is driven; then, neglecting the inertia of the pile, and supposing the ram and pile to be perfectly hard,

$$S = \frac{WH}{R} \quad \ldots\ldots\ldots\ldots \quad (1)$$

But the ram and especially the pile are not perfectly hard; they are compressible and elastic, although imperfectly so. Let therefore A and B be the hardness of the ram and of the pile; then the space through which a nail is driven, that is a body whose inertia may be neglected, is

$$S = \frac{WH}{R} - \left(\frac{1}{A} + \frac{1}{B}\right)\frac{R}{2} \quad \ldots\ldots\ldots \quad (2)$$

as given in Whewell's work before mentioned, to which reference is made for the steps of the present investigation. The last term in this equation is therefore the defect arising from imperfect hardness, and is less as the hardness is greater, or as the joint compressibility of the ram and pile is less.

This equation leads to a result of great practical importance. For every position of the pile there is a certain value of the resistance R; and for this value of R there is some value of H, the height of fall, which will make the second side of the equation (2) equal to zero. There is therefore a certain fall which will not drive the pile at all, however great the number of blows, the only effect produced being to soften the head of the pile by continual hammering, and consequently to make matters worse. This is not a theoretical case only: in driving the piles for the foundations of the piers of the High Level Bridge at Newcastle it frequently happened that Nasmyth's steam pile driver hammered on the head of a pile for a considerable time without producing any other effect than softening the head of the pile, and making it necessary to cut it off several times. It must be observed that this effect, or rather absence of effect, is due not to the

compressibility of the pile only, but to the total amount of yielding from whatever cause arising. If the soil yields the same result follows; and yielding of the soil is worse than any ordinary compressibility in the pile, because it is far greater in amount. This accounts for the difficulty of driving in sand and for the rebound of the pile that has been often observed.

But although it may seldom happen that absolutely no effect is produced, a diminution of effect must always take place; and the important point to be noticed is that, for a given degree of hardness and given resistance, the *proportion* of loss is diminished by increasing the height of the fall. For supposing the fall required to compensate for the defect arising from imperfect hardness to be 2 feet, and the actual fall of the ram 4 feet, the loss is then one half; but if the fall be 8 feet, the loss is only one fourth. Now the power required to raise the ram 8 feet is the same as to raise it twice to a height of 4 feet, in the same time; but the useful effect in the first instance is represented by $8 - 2 = 6$, and in the second by $2\,(4 - 2) = 4$; or for the same expenditure of power the useful effect is half as much again with the higher fall.

Again we have from the equation (2) when S the space through which the pile is driven equals zero,

$$\frac{WH}{R} = \left(\frac{1}{A} + \frac{1}{B}\right)\frac{R}{2}$$

$$\text{Whence } H = \frac{1}{2}\left(\frac{1}{A} + \frac{1}{B}\right)\frac{R^2}{W} \quad \ldots\ldots \quad (3)$$

or the height of fall which represents the defect arising from imperfect hardness varies as the square of the resistance and inversely as the weight of the ram. Hence it appears that if the fall be kept constantly the same, as in the steam hammer piling machines, although at first the pile may be driven with facility, a point may be rapidly attained when the resistance and yielding of the pile will render the blow useless. For suppose at a given point the fall required to compensate the defective hardness be 1 foot; then when the resistance is doubled the fall must be 4 feet, whereas the stroke of Nasmyth's ram is only 3 feet. On the other hand when the ram is raised to the same point throughout the driving of a pile, the deeper the pile is in the ground and consequently the greater the resistance, the greater too is the power of the ram.

It appears also from the equation (3) that the heavier the ram, the less is the height of fall lost; and since it was found before that, in regard to the effect when the inertia of the pile is taken into consideration, the heavier the ram is the better the effect, therefore on both accounts it is desirable to have as heavy a ram as possible.

It has been observed that the fall of Nasmyth's ram is equal to 3 feet; and as the writers believe that there is some misconception about the fall to which the stroke of this ram is supposed to be equivalent, it may be well to examine the matter,—assuming, as they believe is the case, that the stroke of the ram, measured from the lowest point to the top of the opening which admits the atmosphere above the piston, is 2 feet 8 inches, and that the remaining length of cylinder above the opening, which is the space allowed for the compression of the air, is 4 inches. The weight of the cylinder and case together is $1\frac{1}{2}$ ton; when therefore the air in the top of the cylinder is compressed to such an extent that its excess of pressure above the atmosphere acting over the area of the cylinder is capable of balancing $1\frac{1}{2}$ ton, the case will rise: if it does not rise, the upward motion of the ram has been destroyed before that pressure was attained; in reality however it does rise, but only about $\frac{1}{4}$ inch, showing that the pressure has been just attained. In the fall of the ram, the recoil of the cushion of compressed air acts upon the piston attached to the ram until the piston has passed the opening communicating with the external atmosphere; and the force of the recoil together with the force of gravity acting during the same period accordingly impart the same velocity to the piston as it had when passing the opening in its ascent. The question therefore resolves itself into ascertaining this velocity and the height of fall to which it is equivalent. The velocity is readily determined by calculating the distance required to be moved through by the piston after it has begun to compress the air in the top of the cylinder, in order to produce the degree of compression necessary for balancing the weight of the cylinder and case; remembering that the motion of the piston must cease at that point otherwise the case would be lifted. This distance is found to be $3\frac{1}{4}$ inches, and the velocity produced by the recoil of the air in expanding after its compression and by gravity is the velocity which has been destroyed by the resistance of the air to compression and by gravity, and is that which would be acquired by falling through a height of 4 inches, which is

therefore the extra height of fall due to the cushion of compressed air. The 4 inches being added to the actual fall 2 feet 8 inches gives 3 feet for the total fall of the ram in Nasmyth's pile driver, as before stated.*

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* The following are the details of the calculation :—

Let a = height of cylinder above the opening which admits the atmosphere = 4 inches = ·33 foot ; b = height above the opening to which the piston must rise in order to compress the air sufficiently to balance the weight of the cylinder and case ; x = height of piston above opening at any time ; v = velocity of piston at the point x ; V = velocity of piston on passing the opening ; P = total pressure of atmosphere on piston = 15 lbs. × area of piston = 750 lbs., the diameter of the cylinder being 8 inches ; W = weight of piston and ram = 1½ ton = 3360 lbs.

Then total pressure on piston at point $x = \frac{a}{a-x}P$; therefore, effective pressure $= \frac{a}{a-x}P - P = \frac{x}{a-x}P$; and the accelerating force produced by this pressure $= \frac{x}{a-x}\frac{P}{W}g$; therefore

$$\frac{d^2s}{dt^2} \text{ or } v\frac{dv}{dx} = -g - \frac{x}{a-x}\frac{P}{W}g,$$

$\frac{d^2s}{dt^2}$ being the effective accelerating force at the point x, and the negative sign being taken because x is measured in the opposite direction to that in which the accelerating force acts. Hence, integrating,

$$\frac{v^2}{2} - \frac{V^2}{2} = -gx + \frac{P}{W}gx - a\frac{P}{W}g\log\frac{a}{a-x},$$

since when $x = o$, $v = V$. Also when $x = b$, $v = o$; therefore

$$\frac{V^2}{2g} = b - \frac{P}{W}b + a\frac{P}{W}\log\frac{a}{a-b}.$$

Now $P = 750$ lbs., and weight of cylinder and case = 1½ ton = 3360 lbs.; therefore total pressure on piston when balancing the cylinder and case = 4110 lbs. Hence $a - b = \frac{750}{4110}a$; therefore $b = 3{\cdot}27$ inches = ·27 foot. Therefore

$$\begin{aligned}\frac{V^2}{2g} &= {\cdot}27 - \frac{750}{3360} \times {\cdot}27 + {\cdot}33 \times \frac{750}{3360} \times \log 5{\cdot}48 \\ &= {\cdot}21 + {\cdot}074 \times \log 5{\cdot}48 \\ &= {\cdot}34 \text{ foot} \\ &= 4{\cdot}08 \text{ inches.}\end{aligned}$$

Now $\frac{V^2}{2g}$ is the height due to the velocity V which the piston has on passing the opening both in its ascent and descent ; therefore 4·08 inches is the extra height of fall due to the cushion of compressed air and gravity.

Hence the total fall of the ram is 36·08 inches, or 3 feet.

If the cylinder rises about ¼ inch, as is generally the case, in consequence of the air being compressed above the limit of pressure necessary to balance the weight of the cylinder and case, the extra ¼ inch is merely to be added to the total fall of the ram.

Description of improved Steam Pile Driving Machine.—The new steam pile driver, forming the further subject of the present paper, was designed for the purpose of constructing a wharf or quay on the river Blyth, above the entrance to the proposed new docks near the mouth of the river. A row of piles, placed at intervals of 8 feet from centre to centre, and consisting of whole balks of Memel timber, were to be driven into the ground to a depth of 14 feet 6 inches below the surface, with a batter of 1 inch to a foot; and 15 feet in the rear of this front row, a second row of piles 8 feet long were to be driven wholly into the ground, with a batter of 4 inches to a foot, one of the latter piles being placed behind every alternate face pile with a tie bolt to connect the two. In addition to these two rows of piles it was subsequently ordered that the spaces between the face piles should be filled with sheet piling 12 inches wide by 6 inches thick, driven from 10 to 11 feet below the surface. With the exception of a small portion of the line where there is a bed of very hard gravel, the ground is sand, a soil which presents great difficulties in pile driving; and the surface of the ground varies from a little under to between 2 and 3 feet above low water of ordinary spring tides, which rise at Blyth about 13 feet.

For accomplishing the above work, the new machine was constructed as shown in Figs. 1 and 2, Plates 97 and 98, in accordance with the principles laid down in the first part of this paper. Fig. 1, Plate 97, is a side elevation of the machine; and Fig. 2, Plate 98, an end elevation.

The machine is designed to drive two face piles and one land tie pile whilst in one position. It consists of two ordinary leading frames AA, braced together at the proper distance apart for the two piles to be driven; these frames turn on hinges B, for the purpose of adjusting them exactly to the required angle of the piles, and are supported at the back by ties C. The timber frame D to which the hinges and ties are attached is independent of the lower platform E upon which it rests, and is capable of being moved backwards or forwards upon it, so as to bring the leaders A into the exact position for the piles; but when in work the frame D is held down to the lower platform E by bolts. The movement of the frame D upon the platform E is accomplished by means of wheels F on each side; under the wheels are placed tapered iron wedges G, so that a small turn of the wheels is sufficient to raise the frame D slightly from the platform E, thereby removing the friction which would prevent motion, and at the same time effecting the small movement necessary for adjust-

ment. The wedges G are then driven out from under the wheels by the blow of a hammer.

The lower framework of timber H is strongly braced together by diagonal ties, and runs upon a railway laid on the ground; it is made sufficiently high to keep the platform E always above high water. The machine is moved along the rails by means of chains attached ahead and astern to screw moorings sunk in the ground; the chains pass round pulleys I fixed to the lower frame, up to the crabs, and wind upon the end drums K; they are stopped or locked on the platform and unwound from the drums when the machine has been moved the required distance.

The leading frame L at the back of the machine for driving the land tie pile is fixed at the required angle, but is not adjustable, any little inaccuracy in its position being unimportant.

On the platform E is placed a portable steam engine M, with two crabs NN, each working a ram O in the usual way. The crabs are furnished with clutches for throwing them in and out of gear, and with brakes. The clutches PP, shown enlarged in Fig. 3, Plate 99, are connected together so that when one drum is in gear the other is out of gear; the means of disconnecting is by the weighted lever Q, which is loose upon the spindle and acts by catching in the notches R. The method of working is as follows:—one drum having been put into gear by the weight on the hand gear lever Q, the ram is being wound up; during this time the lever Q with its weight is turned over to the other side, as shown dotted; the tendency of the weight is then to throw the clutch of the working drum out of gear, but the friction produced by the strain of winding the ram prevents disengagement; when however the strain is relieved by the release of the ram, the weight throws the working drum out of gear, thereby preventing the further ascent of the monkey or claw S which lays hold of the ram, and throws the other drum into gear, which in its turn lifts the other ram. The monkey S of the first ram now descends to lay hold of the ram again, the brake T being put on to check its velocity; and the handle Q is reversed, to be in readiness again to disconnect the clutch of the working drum when the second ram has reached the top. In this way the operation is continuous, the engine is neither stopped nor reversed, and no time is lost.

The clutches and brakes as at first made did not work satisfactorily; the brakes T were originally in one piece with the clutches P, but were

afterwards attached to the drums N; and the bearing surfaces of the clutches were originally perpendicular to the face of the clutch, but the friction between the surfaces in contact was then so great that the lever Q could not readily disconnect them when the strain was relieved, and they were therefore made slightly bevilled, to the extent of about 1 in 5, as shown in Fig. 3, to cause them to separate more easily; after these alterations the machine worked quite satisfactorily.

The weight of the ram O is $1\frac{1}{2}$ ton, and including the weight of the monkey and friction the strain on the chain and machinery is considerably greater. From the high velocity at which the crabs are driven, this strain would be felt as a sudden tug on beginning to raise the ram, which neither chain nor framework could be expected to bear without injury; and hence arose the necessity of providing something in the form of a buffer to mitigate the intensity of the strain. The arrangement adopted is shown in Figs. 4 and 5, Plate 99; it consists of a cylinder U, furnished with a piston on the upper side of which is a strong volute spring requiring $1\frac{1}{2}$ ton to compress it; the travel of the piston is $4\frac{1}{2}$ inches, and the chain is wound up for this length before the ram rises, the strain gradually increasing up to $1\frac{1}{2}$ ton. During the ascent of the ram the spring remains compressed; but on arriving at the top of the machine the ram is suddenly disengaged, and the whole weight being removed, the rebound of so powerful a spring would probably drive the piston through the bottom of the cylinder; this is prevented by admitting air into the cylinder through a small orifice at the bottom and thus providing a cushion for the piston, the orifice being so minute that it takes the whole time of the ascent of the ram to fill the cylinder, and the air cannot escape in a moment. The formation of a vacuum below the piston and the compression of the air above assist the spring in its action.

The piles are floated to the place in rafts; and the rams being made fast at the top of the machine by a pin passed through the leaders A, the working chains are detached and hooked to a pair of dogs fastened on a pile, which is then raised and pitched to its place by the engine. The operation is performed with astonishing quickness, but this depends in a great measure upon the facility obtained by the peculiar kind of hook V, shown enlarged in Fig. 7, for attaching the chain to the monkey; with facility for immediate detachment the hook combines the advantages of great security, strength, and provision against accidental detachment by the upward blow.

In driving sheet piles below the level of the gauge piles by other steam pile driving machines, such as Nasmyth's, it is necessary to use a dolly or intermediate piece of timber, by which a great part of the effect is necessarily lost; but in the new machine the use of a dolly is unnecessary, for by reversing the position of the monkey lever and making it project outwards instead of inwards, so as to clear the frame, the ram will descend to the ground. Figs. 4, 5, and 6, show another method of accomplishing the same object, by means of a long rod W, furnished with a guide X serving to connect the monkey with the ram, however far below the platform the ram may be; this arrangement however is not recommended.

The new pile driver above described was designed to obviate the difficulties that would have attended the adoption of any of the methods previously in use. To drive the piles by the ordinary hand engine would have been a work of considerable time; for not only is a hand engine very slow in its operation, but it would have been only at low water of spring tides that the work could be done. Nor would any of the methods hitherto employed for applying steam power meet the exigencies of the present case. For in the first place the ordinary travelling steam engine could not be applied to work the crabs of hand engines, on account of the rise of the tide; nor could it be placed beyond the influence of the tide, because the beach being flat the space between the new wharf and the shore, which is covered at high water, is considerable; nor could it have been used with a piling engine on a barge, for, not to mention the swell in the river, the ground is in some parts sometimes and in other parts always bare at low water. Nor were the elaborate machines that have been constructed by Nasmyth and Morrison, acting on the principle of the steam hammer, more applicable in the present case. It would have been necessary either to make a strong frame to carry their great weight, in which case rails laid upon the sand would not have been sufficient; or else to drive a large number of extra piles by hand to form a gantrey. Moreover these machines are expensive, and being applicable only to the purpose of driving piles must be idle when that work is done.

From these considerations it was resolved to attempt the present arrangement, which has proved entirely successful. The new machine costs only about a fourth of those referred to above, and is only about a fourth of the weight; it will do as much work per day in many cases, and

will do it better and more cheaply. The whole work of pitching and driving the piles and moving the machine is effected in the new pile driver by a 4 horse power engine, whilst in the others there are two complete separate engines of greater power; and although the latter machines will do more work per minute while they are in motion, in consequence of their greater power, in many cases they will not perform more per day, on account principally of the difficulty of moving them; moreover the great weight of these machines requires that a good foundation and a strong superstructure be provided to carry them, before they can be moved forwards. This was proved in a recent case where Nasmyth's machine was employed, by the fact that, although it could drive one pile in 20 minutes, yet the average per day was only 10 piles driven, an amount of work which the new machine will do easily. With respect to the quality of the work executed, the comparison is again in favour of the new machine; the piles are driven with rare precision, the profile of the work being almost perfect; the heads of the piles are not bruised, and when the rings are removed there is hardly any appearance of abrasion. With regard to cost of working, the steam is kept up all day in the other machines, although the engine is only at work about three hours, and there is a great loss from condensation and leakage in the steam pipes; and as the power and dimensions of both engines and boilers are also much greater than in the new machine, there must necessarily be a larger expenditure of fuel. Although however the other machines were inapplicable in the case for which the new machine was designed, there are circumstances in which they would be more effective than the new engine; such as when a great number of piles were to be driven in a limited area.

One of the disadvantages of contracts for harbour works is the large amount of money sunk in plant, every different kind of work requiring different machinery and tools. The new piling machine however is not a piling machine only, as in the case of the other machines, but may be used also as a steam crab; or if taken to pieces, there is a portable engine complete in itself and applicable to other purposes, a pair of crabs, and the leaders and rams which would go to form two hand piling engines, the only special expense being the lower framework and the fitting together of the various parts.

The CHAIRMAN enquired how long the machine described in the paper had been at work.

Mr. ROBERTSON replied that it had not been long at work, the work having been stopped for a time, but it would be proceeded with again next season. Not much work had at present been performed, though quite sufficient to show the efficient working of the machine.

The CHAIRMAN observed that the weight of $1\frac{1}{2}$ ton for the ram was the same as that used in Nasmyth's steam pile driving engine, and asked whether that was considered the limit of weight for the ram in practice, and what was the greatest height of fall that had been actually employed with that weight.

Mr. ROBERTSON said that $1\frac{1}{2}$ ton was the heaviest ram used in either engine, but he considered it best to employ the greatest weight and the greatest height of fall that the piles would bear without injury. In the present instance the driving began with about the same fall of 3 feet, and the fall increased to as much as 12 and 14 feet towards the end.

The CHAIRMAN asked how many strokes were made on the average compared with Nasmyth's engine, in order to drive the piles to the same depth.

Mr. ROBERTSON replied that about 70 to 80 strokes of the new machine were sufficient on the average to drive a pile to the required depth. In Nasmyth's engine the ram made about 60 strokes per minute, but he was not aware what number of strokes would be required to drive a pile to the same depth; the difference was however great.

Mr. FOTHERGILL enquired what was the size of the piles, and the nature of the ground into which they were driven.

Mr. ROBERTSON said the piles were 12 to 13 inches square and 25 feet long; the ground in which they had been driven at present was hard gravel at the surface with sand beneath.

Mr. FENTON asked whether the relative cost of working as compared with the ordinary pile driving engine had been ascertained.

Mr. ROBERTSON could not state definitely the cost per foot run of pile driving by the machine, as it had not yet been at work long enough to ascertain correctly; but the work was certainly economical, from the expedition with which it was done and the small amount of attendance and steam power required; and the cost of repairs seemed likely to be small. The cost of the machinery amounted to about one quarter of the cost of an ordinary pile driving engine.

Mr. FOTHERGILL thought it would be important to ascertain carefully the total consumption of fuel and expenses of workmen and repairs in executing a considerable amount of work, so as to obtain a correct average cost of performing the work.

The CHAIRMAN enquired whether there had been any occasion to cut off the heads of the piles, on account of their being crushed by the driving, in consequence of the great fall of the ram at the last blows.

Mr. ROBERTSON said that the heads of the piles had never required to be cut, and although so great a fall was given to the ram, there had not been the slightest appearance of crushing or injury on any of the pile heads after being driven; the piles remained as compact at the head after driving as they were when the driving began.

The CHAIRMAN observed that the limit of fall for the ram was in fact the height that would crush or split the pile in the whole number of blows that had to be given, and the number of blows required would be much diminished by the increase in the force of each. He asked what was the cost of construction of the present machine.

Mr. ROBERTSON replied that there had only been this one machine made at present, and the cost was about £450, complete with the portable steam engine and the three rams.

The CHAIRMAN proposed a vote of thanks to Mr. Scott and Mr. Robertson, which was passed; and expressed a hope that they would communicate the results of the further working and comparative expense of the machine, when there had been longer experience of its working.

The following Paper, by Mr. Ebenezer Rogers, of Abercarn, was then read:—

ON THE MANUFACTURE OF CHARCOAL AND COKE.

The importance of the manufacture of charcoal and coke will be at once apparent when it is considered that at present these substances are the agents principally employed in smelting iron and other metallic ores, and in obtaining steam power for railways: yet in this branch of manufacture, until very recently, scarcely any improvements have been made; the plans in use hundreds of years ago are still followed, and the principles or rationale of the process seem scarcely to be known, or at least appear never yet to have been published. A clear and distinct knowledge of the philosophical principles upon which a manufacture or process rests, and of the true aim and end of such manufacture or process, is the basis on which all genuine inventions and improvements must be founded. The writer accordingly proposes in the present paper to examine the several plans which have been used in the process of coaling and coking; and also to investigate the rationale of the process, with a view to further improvement.

In the earliest method supposed to have been employed for manufacturing iron, a site was selected on some high hill exposed to the wind, and a quantity of ore was placed on a large heap of wood; and a shallow hole was made in the earth to receive the metal, the name "hearth" being still used for this part of the furnace. To obtain the metal in a soft malleable state it was necessary to allow the mass to cool gradually; and for this purpose the fire was covered at the end of the process with earth or turf in a conical shape. The wood so covered would thus be converted into charcoal: and it would also soon be noticed that the ore did not fuse until the wood in contact with it was coaled; that the hottest part of the fire was in the coaled portion; and that the force of the fire was greatly diminished when the flame was allowed to expand itself in an unconfined space. This would lead to the next step, the discovery of the wind furnace, in which the fire was sheltered and confined by a surrounding wall, and the wind admitted only by holes at the bottom where it acted as a blast; then in this furnace charcoal by itself could be used, thus advancing the process to the second stage, in which prepared fuel is employed instead of raw wood.

The earliest plan of *coaling wood*, as the manufacture of charcoal was termed and is still called, is shown in Fig. 1, Plate 100. A piece of

ground is levelled at some convenient spot in the forest, which is termed the "hearth" or "earth;" in the centre of this a thick pole or bundle of brushwood is placed, around which the wood is arranged as shown in the figure, some of the pieces being laid horizontally and others set up at an inclination; or the wood may be placed altogether at any steep angle, sloping outwards from the centre to form a flattened cone, which when complete is usually called a heap; the object, whichever way the wood is placed, is to obtain a free circulation of air under the heap, to communicate with the chimney in the centre, which is formed by then withdrawing the centre pole or bundle of brushwood. The larger wood should if convenient be at the bottom of the heap, and the outside packed as close as possible; the heap is then covered with small brushwood, and afterwards with turf, or the material most impervious to air which can be conveniently obtained. A fire is lighted in the centre chimney, and by leaving openings in the outside covering at the bottom of the heap, the fire soon extends, and can be guided to any part by making temporary openings to admit the air. When the heap is sufficiently fired all the openings are closed, and lastly the chimney itself. The fire will always extend most rapidly on the side facing or towards the wind; and great care must be taken to watch and check this, by keeping the covering on that side in good order. The charcoal burner must always be careful to spread the fire as evenly as possible through the heap, and after it is coaled to stop it down carefully; he can always accelerate the process in any part of the heap if well built, by opening the outside to admit air freely: but if he finds this does not act, from any fault in setting the wood, he had better open a hole with a bar at the place required and light a fire in the hole; this will soon communicate with the main fire in the heap. As soon as the smoke and white flame cease to escape at the vents, the whole heap must be closed from the air as carefully as possible, until the charcoal has quite cooled and is ready to draw. The fire must never burn too fast; the slower the process, if the fire is steady and regular, the better the yield of charcoal. Hard close grained woods take a longer time to coal than soft open grained woods, and should be placed in the heap accordingly. These technical instructions, handed down in the forests for ages as secrets from father to son amongst the coalliers in every country in Europe, are the results of long practical experience, and strictly accord with the true principles on which the process is based.

Figs. 2 and 3 are a longitudinal section and plan of another shape of heap, for coaling wood, technically termed a charcoal mound. It is used where circumstances are favorable for getting large quantities of wood together at the same spot. Dr. Ure * describes this mode of coaling as used in Germany, and adds, "Charring of wood in mounds (*Haufe* or *liegende Werke*) differs from that in the *Meiler*," or charcoal heap above described, "because the wood in the *Haufe* is successively charred, and the charcoal is raked out by little and little." The wood is laid in the form of a long narrow mound, which does not require a centre chimney and may be worked of any length, portions being uncovered in succession according as the process is found to be completed; the wood is in billets 6 or 8 feet long, laid over one another transversely in the mound, and covered over with ashes.

A very large portion of the wood formerly converted into charcoal by the processes above described is now in this country treated in a different manner. The wood is now used for the production of pyroxylic spirit, vinegar, and other substances; for this purpose it is distilled in close retorts, and the charcoal is the residue. The details of this manufacture do not come within the range of the present paper, except so far as they bear upon the charcoal alone; an able article in the work on "Chemistry relating to the Arts and Manufactures," by Dr. Sheridan Muspratt, gives much detailed information on the subject. But from the low heat used in the distillation and other causes the charcoal made in this manner is much inferior in quality to that made by the open coaling process; it is not so hard or dense, and will not maintain so high a temperature in combustion.

About the middle of the seventeenth century Great Britain seems to have been so completely disforested, and charcoal to have become so scarce, as practically to destroy for a time the iron manufacture. But, as has many times occurred in the history of man's progress, other means were soon found when the necessity arose, and, like all great discoveries, came at the exact time when required. With the personal suffering which men a little before their time appear generally to meet with, Simon Sturtevant, Rovenson, Dud Dudley, and others, attempted the use of pit coal in the place of charcoal. This change, simple as it appears in looking back upon it from the present day, occupied 150 years; more than five generations passed away during its development.

* Dictionary of Arts, Manufactures, and Mines. "Charcoal."

In the year 1612, Simon Sturtevant in his "Metallica," (an able book, still worthy of careful reading) claims the smelting of iron from pit coal as his invention; and with the inspiration of true genius appears to have seen clearly the necessity of *preparing* the pit coal for use in the smelting furnace. In question 131 in the "Metallica" the reader asks, "What means are to be used to make earth coal as serviceable for metallic purposes as wood or charcoal?" and the answer is, "There are three sorts: the first is to bring earth coal to that equality of heat that wood or charcoal hath; that is to say, that it maketh neither hotter nor colder fire than wood or charcoal doth: the second means is so to order and prepare the pit coal that all noxious properties, which are averse from all metallic substances, may be abstracted in it: the third means is the addition and infusion of those deficient properties, which, as they are in charcoal, so are they to be found in pit coal." The first and second of these requirements have been at the present day partly accomplished; but the third is still a work to be done. Some misfortunes overtook Sturtevant soon after this, for in 1613 his patent was cancelled and he was then an outlaw; with him the master spirit seems to have disappeared, and it is unnecessary to examine the works of his immediate successors.

In the year 1665, or half a century later, Dud Dudley in his "Metallum Martis" describes the various attempts made by different inventors to use pit coal before his time; and claims for himself the merit of having succeeded in the invention. All these early inventors seem however to have practically failed. Dr. Plot, in his history of Staffordshire, published in 1686, states that "the last effort that was made in this country for making iron with pit coal was with raw coal, by a Mr. Blewstone, a German, who built his furnace at Wednesbury, so ingeniously contrived that only the flame of the coal should come to the ore, with several other contrivances, that many were of opinion he would succeed in it;" but it seems he did not. This distinct mention of using raw coal would probably imply that it was unusual at that time; and by a further passage from the same author it appears that coke was then well known; for he states "They have a way of charring the coal, in all particulars the same as they do wood; whence the coal is freed from those noxious steams that would otherwise give the malt an ill odour. The coal thus prepared they call cokes, which conceives as strong a heat almost as charcoal itself, and is as fit for most other uses, but for melting, fining, and refining of iron, which it

cannot be brought to do, though attempted by the most skilful and curious artists."

In "Scrivenor's History of the Iron Trade," published in 1841, it is stated that "the various attempts to substitute pit coal for charcoal having thus failed, no further experiments were made till the early part of the next century, when pit coal was first used by Mr. Abraham Darby in his furnace at Colebrook Dale in 1713; and in the 46th volume of the Philosophical Transactions, published in the year 1747, it is stated that Mr. Ford, from iron ore and coal both got in the same Dale (Colebrook), makes iron brittle or tough as he pleases, there being cannon thus cast so soft as to bear turning like wrought iron."

It appears from the statements made by Simon Sturtevant, which are confirmed by Dud Dudley, that in 1612 the annual production of iron in Great Britain exceeded 180,000 tons; this quantity gradually diminished, until in 1740 the total make was only 17,350 tons.

The exact time when pit coal was first coked is not ascertained. The transition from *coaling wood* to *coking pit coal*, with some of the Staffordshire coals especially, was so plain, after the suggestions published by Sturtevant, that probably it was commenced at several places almost simultaneously, and afforded no special claim for any one person.

Fig. 4 is a section of a coke heap as still extensively used, the large heaps having a brick chimney instead of the rude chimney of the charcoal heap shown in Fig. 1; the coker should take care to place the coal with the bed or grain endways as often as possible, more especially at the bottom of the heap. Figs. 5 and 6 are a longitudinal section and plan of a long coke mound, corresponding closely with the long charcoal mound shown in Figs. 2 and 3; this is built of any length, and the large coal piled in the middle and bottom. It is evident that these modes of coking pit coal are a mere repetition of the plans for coaling wood; the present cokers are truly the legitimate trade descendants of the ancient forest coalliers, and the same instructions given before for coaling wood apply to coking coal.

At the close of the last century the iron manufacture was becoming a most important industrial pursuit in Great Britain; the continued existence of our nationality depended upon it. The great pressure on the resources of the country, occasioned by long wars, hastened the development of the inventions of Watt, in the steam engine; Cort, in the puddling

process and grooved rollers for iron; and amongst others seeking to benefit this manufacture, the attention of Lord Dundonald about the year 1798 was directed to the great waste of small coal, and the gaseous products of coal. Figs. 7, 8, and 9, Plate 101, are longitudinal and transverse sections of the ovens invented by Lord Dundonald. The ovens A are built in two tiers, the one over the other; the flame from the lower ovens is carried by flues B around the outside of the upper ovens, and keeps them always at a red heat; the upper ovens are charged with small coal and closely luted, thus forming a series of retorts, in which the volatile products of the coal are distilled and pass off through the pipe C; the tar and ammonia are condensed, and the gas is used for lighting the works.

When small coal of bituminous quality is placed upon a coke hearth and the heap built upon it, it is coked by radiated heat from the heap; in this manner large quantities of small coal are still coked at some ironworks. This fact being observed would lead to the construction of ovens, where the arch over the coal being kept at a red heat answers the purpose of the coke heap. The small coal of Yorkshire and the North of England being of a bituminous character and well adapted for coking, ovens of various shapes were erected for the purpose; the hemispherical ovens, described by Mr. Parkes about thirty years ago as in use at that time at Sheffield, seem to have been and still are a favorite shape in the north. Fig. 10, Plate 101, is a vertical section of one of the hemispherical ovens, and Fig. 11 a sectional plan. An improved and carefully considered modification of the plan was adopted in the ovens erected at the Camden Town Station on the opening of the London and Birmingham Railway; and this construction has been extensively used in this country and on the continent, having been found the best on this plan.

The great demand for superior coke, consequent on the development of the railway system, has led to attempts at improvement in every direction; and various plans have been brought out in Great Britain and on the Continent for ovens of almost every conceivable shape, with flues under the ovens, at the sides, above, around, &c. The leading object in all these plans is to keep the oven at a high temperature, that being found an essential condition for the manufacture of dense hard coke, as afterwards explained. Figs. 12 to 19, Plate 102, show the construction of one of the most approved forms of ovens for coking some coals containing only a small quantity of bituminous matter and requiring a high temperature;

in this plan the waste gases are burnt in the flues, and thus made use of to increase the temperature of the ovens.

A short time ago a plan was mentioned to the writer as having been used in Westphalia, by which wood was charred in small kilns; as the form of kiln described was quite new to him, it led him to some reflection as to the principles on which it acted, which were found to be so simple and effective, that he determined to apply them on a large scale for coking coal. The result has been that in the course of a few months the original idea has been so satisfactorily matured and developed, that instead of coking 6 tons of coal in an oven costing £80, 150 tons of coal are now being coked at once in a kiln costing less than the former single oven.

Figs. 20 and 21, Plate 103, are a side elevation and plan of one of the new coking kilns to a small scale; Figs. 22 and 23 are an enlarged transverse section and plan.

DD are the walls of the kiln, which are provided with horizontal flues E F, which open into the side or bottom of the mass of coal. Connected with each of these flues are the vertical chimneys G H. The dotted lines I I, Figs. 21 and 23, represent a moveable railway, by which the coal may be brought into the kiln and the coke removed from it. In filling the kiln with coal, care is taken to preserve transverse passages or flues for the air and gases between the corresponding flues E F in the opposite walls. This is effected by building or constructing the passages at the time with the larger pieces of coal, or else by means of channels or flues permanently formed in the bed of the kiln. When the coal is of different sizes it is also advantageous to let the size of the pieces diminish towards the top of the mass. The surface of the coal when filled in is covered with small coal, ashes, or other suitable material.

When the kiln is filled, the openings K at the ends are built up with bricks, as shown dotted; the kiln is not covered by an arch, but left entirely open at the top. The apertures of the flues F and chimneys G are then closed, as shown in Fig. 22, and the coal is ignited through the flues E; the air then enters the flues E and passes through the coal, and then ascends the chimneys H, as shown by the arrows. When the current of air has proceeded in this direction for some hours, the flues E and chimneys H are closed, and F and G are opened, which reverses the direction of the current of air through the mass. This alternation of the current is repeated as often

as may be required. At the same time air descends through the upper surface of the mass of coal. When the mass is well ignited, which takes place in from 24 to 36 hours, the external apertures of the flues E and F are closed, and the chimneys G and H opened; the air now enters through the upper surface of the coal only, and descends through the mass of the coal, the products of combustion passing up the chimneys.

The coking gradually ascends from the bottom of the mass to the top, and can be easily regulated or equalized by opening or closing wholly or partially the apertures of the flues or chimneys. The top surface of the coal being kept cool by the descending current of air, the workman is enabled to walk over it during the operation; he inserts from time to time at different parts of the surface an iron bar, which is easily pushed down until it reaches the mass of coke, by which its further descent is prevented. In this way the workman gauges the depth at which the coking process is taking place, and if he finds it to have progressed higher at one part than at another, he closes the chimneys communicating with that part, and thus retards the process there. This gauging of the surface is carried on without difficulty until the coking process has arrived close to the top. The gases and tarry vapors produced by the distillation or combustion descend through the interstices of the incandescent mass below, and there deposit a portion of the carbon contained in them, the residual gases passing up the chimneys. The coke at the lower part of the kiln is effectually protected from the action of the air, by being surrounded and enveloped in the gases and vapors which descend through it and are non-supporters of combustion.

When the mass of coal has been coked up to the top, which takes place in about 7 days, it is quenched with water, the walls closing the end openings K are taken down, and the coke is removed. When a portion has been removed, the moveable railway I is laid into the kiln, so as to facilitate the removal of the remainder of the coke.

The flues E and F may enter at the bottom of the kiln, or at the sides above the bottom as in Fig. 22; in the latter case the space below, up to the level of the bottom of the flues, may be filled with small coal, which becomes coked by the radiated heat from the incandescent mass above. The transverse passages through the mass are then constructed upon this bed of small coal with the larger lumps of coal, as before mentioned. The flues and chimneys need not necessarily be horizontal and vertical;

and instead of connecting a separate chimney with each transverse flue, flues may be constructed longitudinally in the walls of the kiln, so as to connect two or more of the transverse flues, which are then regulated by dampers, conveying the gaseous products from them into chimneys of any convenient height; the arrangement first described however, and shown in the drawings, is preferred. The gaseous products may be collected, and tar and ammonia and other chemical compounds manufactured from them by the usual modes. The coking or charring of peat and wood may be effected in a similar manner to that already described with regard to coal.

The new kilns have proved entirely successful; they are already in use at some of the largest iron works in the kingdom, and are being erected at a number of other works. The great saving in first cost of oven, economy in working and maintenance, increased yield, and improved quality of coke, will probably soon cause this mode of coking to supersede the others now in use. The kilns are most advantageously made about 14 feet in width, and 90 feet in length, and 7 feet 6 inches in height; this size of kiln contains about 150 tons of coal.

It is well known that wood before coaling, however dry, will not answer for smelting purposes; because a sufficient temperature cannot be maintained during its combustion in the furnace. The reason of this is apparent, if it is considered that the process of coaling drives off the water and gases of the wood, and thus hardens the substance of which the cells are formed, leaving nothing but a porous mass formed of a number of small cells or tubes, which allow the blast of air to act upon a very large surface of carbon within a small space, producing a very high temperature from the concentration and consequent intensity of the combustion. It has been ascertained that one cubic inch of beech wood charcoal presents in this manner, at the lowest computation, a surface of one hundred square feet; and the surface exposed in sound close grained woods is probably much greater. The hard woods, such as oak, beech, &c., are known to be the best for smelting; in these the tubes or cells are small, and the total surface exposed is consequently larger. The process of coking also in a similar manner converts the coal into a porous mass; but this is done during the melting of the coal, at which moment the gases in liberating themselves form very minute bubbles; but the practical result is the same as in wood coal, allowing a large surface of carbon

in a small space to be acted upon by the blast. As a general rule, coke made rapidly has larger pores and is lighter than coke made slowly; it accordingly bears less blast, and crumbles too easily in the furnace.

The process of coking in the ordinary ovens may be thus explained. When the oven is filled with a proper charge, the coal is fired at the surface by the radiated heat from the roof; enough air is admitted to consume the gases given off by the coal, and thus a high temperature is maintained in the roof of the oven. The coal is by this means melted; and those portions of it, which under the influence of a high temperature can of themselves form gaseous compounds, are now given off, forming at the moment of their liberation small bubbles or cells; the coke now left is quite safe from waste, unless a further supply of air is allowed to have access to it. At this stage of the process, the coke assumes a pentagonal or five-sided shape, and columnar structure. When the coke is left exposed to heat for some time after it is formed, it becomes harder and works better from being less liable to crush in the furnace and decrepitate on exposure to the blast.

It has been often remarked as a strange fact, that the hotter the oven, the better the yield of coke; hence all the arrangements of flues to keep up the temperature of the ovens. This fact is however the result of laws well known to chemists. When the coal is melted as above mentioned, the hydrogen in the coal takes up two atoms of carbon for each two atoms of hydrogen, forming bicarburetted hydrogen gas (C_2H_2); this at once escapes, but it has to pass upwards through the red hot coke above, which is at a higher temperature than the melted coal below. Now when bicarburetted hydrogen gas is exposed to a bright red heat it is decomposed, forming carburetted hydrogen gas (C H_2), and depositing one atom or one half of its carbon in a solid form. Consequently in the process of coking, if the oven is in good working order and the coke hot enough, the liberated carbon is detained in its passage upwards, and either absorbed by the coke or crystallized *per se* upon it. This is simply illustrated by passing ordinary illuminating gas through a tube heated to a bright red heat; the tube will soon become coated internally and ultimately filled with a carbonaceous deposit produced by the decomposition of the bicarburetted hydrogen contained in the gas.

It is found that some coal, which is too dry or not sufficiently bituminous to coke when put into the oven by itself in lumps, will coke

perfectly if crushed small and well wetted with water and charged in this state; this fact if followed out would lead to an examination of the chemical nature of the effect produced by the water, and would point the way to further improvements; but that branch of the subject cannot be pursued in the present paper.

The utilization of the large quantities of heating power and of the important chemical substances produced and now wasted in the manufacture of charcoal and coke, is a subject deserving serious consideration; and if the foregoing remarks be the means of throwing new light on the subject, and directing the careful attention of some thinking minds to it, the aim of the writer is attained.

Mr. Rogers exhibited a large block of coke 3 feet long, made in one of the new kilns, and a model of a kiln.

The Chairman enquired whether there were any of the new coking kilns at work in Staffordshire.

Mr. Rogers replied that there were no kilns at present in Staffordshire, but many were working in South Wales, and their adoption was now extending rapidly in other districts. In coking the dry semi-anthracite coal used in the South Wales ironworks a great heat was required, and expensive constructions of ovens on the most improved plans were generally employed for the purpose, having flues for burning the waste gases, in order to maintain a high temperature in the crowns of the ovens. An outlay of £80 was required in these ovens to yield a supply of one ton of coke per day; but with the new coking kilns £4 only was necessary for the same production, thus effecting a great saving in capital, the importance of which would be evident when it was considered that many hundreds of tons of coke per day were regularly consumed in some of the large ironworks.

A great source of expense in the ovens was the heavy cost of repairs, in consequence of their complicated construction of firebrick and ironwork; but the new kilns being built in the simplest manner of rough rubble-work, with only a plain lining of firebrick and without any ironwork, reduced the expense of repairs to a very small sum. In the kilns natural means were employed to effect what had been accomplished in the closed ovens by artificial plans; in the latter a waste of coke arose from the air cutting across the surface and burning away a considerable portion during the process of coking, the prevention of which depended on the air-tight construction of the ovens; but in the new kilns this loss was prevented by inverting the action; a considerable portion of the gaseous carbon was arrested and deposited again in a solid form upon the heated coke at the bottom of the kiln, instead of passing off as gas; also the whole of the incandescent coke was enveloped in an atmosphere of carburetted hydrogen, carbonic oxide, and nitrogen gases, which would not support combustion, and was thus protected from being wasted by burning.

The Chairman asked what was the greatest yield of coke obtained from the new kilns in regular working.

Mr. Rogers said the best kilns in construction and working were those at the Ebbw Vale Iron Works, where as much as 18 cwt. of coke per ton of coal had been obtained, amounting to almost the whole theoretical quantity of carbon contained originally in the coal, that particular coal being of very good quality. The greatly increased yield of coke obtained by means of the new kilns, as compared with ovens occupying the same space, was found a great advantage in large ironworks, where they were sometimes driven to great straits to keep up the supply of coke for the blast furnaces.

Mr. Clift asked whether the horizontal flues were entirely formed by blocks of coal in filling up the kiln, without being previously constructed in the bottom. He should not have expected a sufficient draught could be maintained by the short vertical flues alone without any chimneys rising above the top level.

Mr. Rogers said the transverse horizontal flues were formed only roughly in charging the coal, the floor of the kiln being quite level and solid; the flues were readily made with little trouble, no other care being required than to lay the larger blocks of coal at the bottom in the form of a rough drain running across between the flue openings on opposite

sides, the rest of the coal being then filled in to the top of the kiln. In the largest kilns the horizontal flues were 12 or 18 inches above the level of the bottom, and the bottom was filled up to the flues with small coal, which became coked by radiation downwards on the old principle, thus saving the loss of the small coal ordinarily lying about the works without being used.

There was no difficulty in obtaining a draught through the flues; the heat rarefied the air in the vertical flues, and though their length was so short, allowing only 6 inches difference of height for the column of heated air, they were still found to give sufficient draught to keep up the operation fully; and it was remarkable how great a power existed for readily increasing and regulating the draught and rate of coking throughout the entire area of the kiln.

Mr. Clift did not understand how so much as 18 cwt. of coke could be obtained per ton of coal by any coking process, as the oxygen would inevitably carry off some carbon in the form of carbonic acid and carbonic oxide, besides the portion passing off as carburetted hydrogen gas; he doubted whether there were originally so much as 18 cwt. of carbon per ton in most coals: he had found that a large proportion of water, amounting to fully 2 cwt. per ton, was given off in close distillation from Welsh coals in the process of gas manufacture, leaving less than 18 cwt. of carbon.

Mr. Rogers thought that was an unusual proportion of water to be obtained by distillation, as the principal source would be from combination of the hydrogen and oxygen in the coal, unless the coal was very wet. There was generally, he believed, about 80 to 90 per cent. of carbon in the Welsh coal used for making coke, or about 16 or 18 cwt. in 1 ton of coal; this coal was of a dry nature, not suitable for gas manufacture, and a different quality from the coal used for that purpose.

Mr. Ramsbottom asked whether the new plan of coking was found to get rid of the sulphur from the coal as thoroughly as by coking in ovens.

Mr. Rogers said the sulphur seemed to be well got rid of, as far as could be judged from the quality of the coke in use in the blast furnace, which had proved quite satisfactory. The removal of the sulphur was however principally effected by the water in quenching the coke when drawn, the effect of which would be the same in both plans.

Mr. Cowper asked what proportion of hydrogen there was in the coal from which the coke exhibited was made, whether as much as 10 per cent., as the quantity of hydrogen would materially affect the yield of coke that could be obtained; also how much water was added to the coke by the quenching.

Mr. Rogers did not recollect the exact composition of the coal in question; but the best Welsh coals seldom contained more than 5 per cent. of hydrogen, and the average had been found to be below that amount. The coal from which the specimen of coke exhibited had been made yielded 17¼ cwt. of coke per ton of coal. The hard compact Welsh furnace coke if carefully managed did not absorb more than 5 per cent. of water in quenching, but would take up more water if purposely saturated.

Mr. Clift asked what was the regular yield from the same coal when coked in the ordinary ovens.

Mr. Rogers replied that about 16 cwt. per ton or perhaps a little more would be produced in the ovens; and from 16 to 17 cwt. per ton was the yield obtained in the Welsh ironworks with the best construction of ovens and from the best qualities of coal.

Mr. Cowper enquired whether the coal was washed previously to being coked, as he believed was the ordinary practice in coking the Welsh coal; as the water remaining with the coal would affect the yield.

Mr. Rogers replied that in the trial where 18 cwt. of coke per ton of coal was obtained the coal was not washed, but weighed and put into the kiln direct from the pit; it would then be tolerably dry, and the proportionate yield would thus be slightly increased as compared with wet coal: the ordinary plan was to wash the coal and charge the ovens with coal in the wet state. The yield obtained in the trial of the new kiln was considered so unusual that special measures had been taken to prevent any mistake, and an accurate weighing machine employed to check the quantities of coal and coke; but the result as to the increased yield obtained from the new kilns was fully confirmed.

Mr. Craig asked whether coke suitable for locomotives could be made by the new process; he had previously made a trial of the Abercarn coke for this purpose, but had found it too light and not suitable. He enquired what was the comparative cost of manufacture by the new process as compared with the ordinary oven coke.

Mr. Rogers replied that only blast furnace coke had been made at present in the new kilns; but he had no doubt good locomotive coke might be made in them, by retarding the process so as to produce a slower burnt coke and consequently of harder quality: the coke now made at Abercarn was superior in quality to that made previously, a different seam of coal of better quality being now worked.

The heating power of different sorts of coke depended upon their close or open nature, and the great heating power of charcoal was owing to the great surface exposed for combustion in a small space. Some coal would coke only in large pores, and could not compete with coals producing coke with small pores, in which the total surface would be much greater. The longer the coke was exposed to the heat of the oven or kiln, the harder was the coke produced; and a better result was obtained, as there was less loss from waste of the coke than with a lighter description.

The ordinary cost of coking he believed ranged from about 10*d.* per ton in the hemispherical ovens, exclusive of repairs, to 18*d.* per ton in the improved and more expensive rectangular ovens, inclusive of repairs. In the new kiln the cost of working could be but little, and did not exceed 6*d.* per ton, as the men only filled the coal direct into the kiln after laying the bottom flues; and in some places the coal was actually tipped into the kiln from the colliery wagons working at the higher level, and the coke wagons were afterwards run into the kiln to be loaded direct from the heap of coke when burnt, thus reducing the labour of working to a minimum. The charging of these kilns was in fact scarcely more than the ordinary stacking of the coal for storing; indeed additional kilns were being constructed at some of the large ironworks, as a convenient means of storing large quantities of coal, ready for coking whenever required without any further labour for moving it.

Mr. Craig observed that the new plan might be expected to save fully half the cost of coking, and would prove a valuable source of economy in the cost of locomotive fuel if the process could be satisfactorily applied; he hoped the adoption of the new kilns would be extended to the manufacture of locomotive coke.

Mr. Rogers remarked that the kilns constructed at Ebbw Vale and Victoria Iron Works for making furnace coke were mostly of the size that had been described, holding 150 tons of coal each, which he thought was about the best size for working.

Mr. COCHRANE asked whether the new plan of kiln was likely to be applicable to coking the South Staffordshire coal.

Mr. ROGERS thought it might answer for coking the large coal, but could not say whether it would be practicable to coke the small coal by that method; a thorough process of washing would be required to prepare the small coal, which was otherwise too much mixed with earthy impurities.

The CHAIRMAN proposed a vote of thanks to Mr. Rogers for his interesting paper and the specimens he had exhibited, which was passed; and expressed a wish that he would communicate the results of the further application of the process.

The following Paper, by Mr. William Waller, of Lincoln, was then read :—

ON THE APPLICATION OF STEAM POWER TO AGRICULTURAL PURPOSES.

III. FIELD IMPLEMENTS.

In the two preceding papers under the present title the writer has endeavoured to show the application of Steam Power to the purposes of Agriculture; in the first as to the Steam Engine itself, and in the second as to the Barn Machinery. It now remains to consider the third branch of the subject, namely, the "Field Implements" for the cultivation of the ground.

The most important of the field implements are the plough, the harrow, the various seed planters, drills, and dibbling machines.

The plough appears to have been one of the most ancient field implements, and in the earliest historic records ploughing is spoken of in connection with sowing and reaping, and the furrow is mentioned with the seed and the harrow; whence there is little doubt that the use of the plough corresponded to a certain extent with that at the present day. Ploughing is supposed to have been at first practised merely to make a furrow, in which the seed was to be laid and afterwards covered up by the harrow, to shield it from the sun's rays during the germinating process, as well as to hide it from birds. The Romans are said to have had ploughs similar to ours of the present day, both with and without mouldboards, with and without coulters, with and without wheels. Oxen were employed to draw these implements, having them attached to their necks. Even so late as 1634 it appears that an act was passed by the Irish Parliament against "plowing by the tayle," whereby the breed of animals was impaired, leaving it to be inferred that such was then practised. The modern plough was designed by Dutch engineers who came over to drain the fen districts; the first known in this country was constructed by Joseph Foljambe under the direction of Walter Blythe of Rotherham, and a patent was obtained for one in 1730.

On the stiff land of this country another process beyond mere ploughing is necessary; and therefore the first point to be considered is, what is cultivation? Cultivation is well defined by a recent writer, who is also a

practical farmer, to be thoroughly inverting and mixing the soil, powdering it fine, and leaving it fit for seed.* The plough and the spade have been hitherto employed for this purpose, the former with a horizontal motion like a planing machine, and the latter with a vertical motion. These are both slow in their motion, whereas the engine which it is sought to harness to the same work has a quick rotary motion, and the two thus appear totally at variance with one another. An engine will indeed draw as a horse, or dig as a man, and it has been attempted to apply the rectilinear motion of the piston direct, without the intervention of the rotary motion; but it is not in accordance with the principles of the steam engine to exert its force in these ways; a rotary motion is the only one which can be relied upon as steady and certain, and here the engine is at its proper action. It has to be determined then whether cultivation can be attained by other action than that of the plough or spade, both of which simply "pare off the soil piecemeal, invert it, and leave it to await a further process."

In applying steam power in the place of animal power or human labour, it seems an indirect process to convert the rectilinear motion of the piston of a steam engine into the rotary motion of the driving pulley, and then communicate this rotary motion in order to obtain a rectilinear movement to do work that appears to be adapted to a rectilinear motion alone. In other applications of the steam engine the tools previously used have given way to tools specially adapted to the new power: thus in the barn works, the flail has been replaced by the threshing drum; in the propulsion of vessels, the oar has given place to the paddle wheel and screw; and the hand saw and cross cut saw are converted into the circular saw. In the present case the proper tools for performing the required work have yet to be supplied to the engine, in order to place it in a fair position with regard to the work to be done.

The use of high pressure steam for agricultural purposes has been strongly advocated by Mr. Collinson Hall, who has always opposed the stringent rule of the Royal Agricultural Society as to the limit of 45 to 50 lbs. per square inch for the pressure; he is already using 200 lbs., and recommends 320 lbs. per square inch. An increase of pressure would allow of lighter engines, and one point would then be gained in favour of locomotive traction.

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* "Chronicles of a Clay Farm," by C. Wren Hoskyns, Esq.

The principal plans that have been brought forward for the application of steam power to the field implements of a farm may be divided into the five following classes, the four first of which have representatives in actual use at the present time :—

I.—Locomotive engines dragging implements.
II.—Locomotive engines working rotary cultivators.
III.—Portable engines dragging implements by means of ropes and windlasses.
IV.—Portable engines driving implements by means of endless ropes.
V.—Locomotive engines working spades and other digging implements.

Class I—locomotive engines dragging implements—is represented by Willis's Farmer's Locomotive Engine and Boydell's Steam Horse or Traction Engine. These engines are used both as portable engines and as locomotives, being fixed at their work, but ready to drag any implement when required; they take the place of horses on a farm, and perform all the work that horses can do. Willis's engine is a small locomotive, with gearing to work the driving wheels which have flat tyres to propel by adhesion.

Boydell's engine is an ordinary double-cylinder agricultural engine, having the "endless railway" attached to the wheels, as shown in Figs. 1, 2, and 3, Plate 104. The endless railway consists of a series of shoes A applied to the wheels B, the number of the shoes being proportional to the circumference. The shape of the shoe may be varied; the form preferred is rounded on the surface on which the wheel acts, so that a stone would not rest upon it, and the tyre of the wheel in rolling forwards would press stones out of the way; or a triangular rail may be used, with the vertical angle rounded off for the wheel to roll upon, made of wood shod with iron, or wholly of iron. The sleepers A are longer than the rails, projecting beyond them at each end on the alternate sides, and thus forming a joint; so that, though the ends of the rails abut against each other immediately under the wheel, the back and exterior projection of the front sleeper extends behind the joint of the rails, while the front and interior projection of the back sleeper extends in front of the joint, thus forming a sleeper or bearing to the joint itself, which otherwise would be without a bearing and liable to tilt. The sleepers may be of any breadth from 6 to 15 inches, and are attached to the outside of the felloes B by ingenious mechanical contrivances. A strong bar of iron C is bent into the form of a sharp pointed or gothic arch, bolted to the sleeper with four strong bolts; at the

top of the arch or curved bar is a strong pivot analogous to that of the beam of a balance. The bar C works in a strong iron box D curved at the top and having a notch at each end of the curve in which the pivot works when raising or lowering the sleeper. The curve of each side of the bent bar C is an arc of a cycloid formed by a point in the circumference of the wheel in ascending or descending; and the length of each arc is such that when the two lowest sleepers are suspended freely from their respective pivots the two rails form tangents to the wheel at the point vertically under the centre. The boxes D in which the cycloidal bars work are bolted to the felloes parallel to the tyre and at equal distances round the wheel.

The engine with which experiments have been made has two cylinders of $6\frac{1}{2}$ inches diameter and 10 inches stroke fixed horizontally on the boiler. The crank shaft carries a flywheel, and also two small 10 leaved driving pinions, one at each end, which gear either into two 96 toothed wheels 5 feet diameter fixed on the travelling wheels, or into two intermediate 20 toothed wheels on a separate shaft, on which are two 10 toothed wheels gearing into the 96 toothed wheels, thus giving a quick and slow motion to the engine at pleasure. The driving pinions can also be thrown out of gear with the carriage wheels, when the engine is required to be stationary for threshing or other purposes. The quick speed of travelling is from $3\frac{1}{2}$ to $4\frac{1}{2}$ miles per hour, and the slow from $1\frac{1}{2}$ to $2\frac{1}{4}$ miles per hour. The weight of the engine without water and coals is about 7 tons; it has a water tank and coal boxes, and can carry $1\frac{1}{2}$ to 2 tons of coal and water.

The above description of Boydell's engine will serve to show the attention that has been given to details to make the steam horse capable of supplanting its living opponent, the farm horse; and with the present implements it is considered by many to be the best adapted of the two for the ends sought to be attained. Several modifications of the endless railway have since been brought forward, but the above is sufficient for the purpose of illustration.

Class II—locomotive engines working rotary cultivators—contains Crosskill's Cultivator and Usher's Locomotive Steam Plough, in both of which a rotary cultivator is worked by a portable engine and pulverises the soil by the rotary scratching or grating action. This class has been rendered familiar in the work by Mr. Wren Hoskyns before referred to, in whose views on the subject the writer coincides, and whose suggestion of a

modification of the clod crusher and the hay tedding machine combined, pulverising the solid ground by its revolutions, has already given rise to an attempt in that direction; but the machine produced is too heavy to allow of the idea being said to be realized at present.

Crosskill's cultivator consists of a serrated roller, or a roller set with knives and cutters; but the plan has not yet been fully carried out in practice.

Usher's locomotive steam plough, represented in Fig. 4, Plate 104, consists of a series of ploughshares EE fixed on a revolving shaft F, by the revolution of which they act upon the ground. The engine is an ordinary double-cylinder agricultural engine, having a pinion on the fly-wheel shaft, gearing into a large wheel G on the shaft H, which forms the centre of the swing frame I. The shaft F mounted with the shares is carried at the outer end of the swing frame I, and driven by the large toothed wheel G gearing into a toothed wheel on the shaft F; and the centres of the toothed wheels are thus always at an invariable distance from each other, while the cut given by the shares is regulated by the adjusting screw and wheels J at the inner extremity of the swing frame I. The machine is guided by a man on the footplate K by wheels gearing into a large toothed wheel or locking plate L on the front axle. When in motion the firebox goes first, giving the propelling roller M and the front wheels the advantage of the hard ground to travel over; the engine thus recedes from the shares, and their action is more that of digging tools than of shares like those of an ordinary plough; whereas if the engine were made to travel in the other direction, the action would combine that of the plough and the digger. The first trial of this machine took place in November, 1851; it is said to travel 2550 yards or 1·45 mile per hour turning over 50 inches wide, making 7 acres ploughed in 10 hours.

Romaine's cultivator is somewhat similar in principle to Usher's, but has a number of flat knives fixed spirally on a revolving drum or shaft, instead of shares.

Locomotive engines working rotary cultivators add to the stock on a farm, by not dispensing with horses; they may indeed be made so as to thresh and perform other operations, but in point of utility they do not come up to Boydell's engine, although in a mechanical point of view they are more correct in their application to the work, the rotary system being carried out.

In Class III—portable engines dragging implements by means of ropes and windlasses—there has been more activity in actual experiment and competition than in any other. It comprises methods of applying steam power direct to the old field implements hitherto in use, and includes the arrangements of Messrs. Fowler, Smith, and Williams. The general description of these plans is as follows;—A portable engine working a winding drum is placed on one of the headlands of a field, and an anchor carriage on the opposite one; between these the plough is dragged across the field by a wire rope passing from the winding drum round a snatch block placed on the anchor carriage, both the ends being attached to the plough frame, and the motion being reversed by means of reversing gearing connected with the drum. The feed or travel of the plough for each set of furrows is altered in various ways: in one, by shifting both engine and anchor carriage after each traverse or course of the plough across the field; in another, by shifting them once only for several courses of the plough, this being accomplished by means of a platform the length of the carriages, having holes in it corresponding to the pitch of the furrows, into which a snatch block is fixed, and shifted one or more holes after each course according as there are one or more ploughshares fixed in the plough frame. In some cases the shifting of the carriages is done by the engine, in others by windlasses.

A simple capstan or winding drum for communicating power from an ordinary portable engine was made and tried in 1849 by Messrs. Clayton, Shuttleworth, and Co., of Lincoln, from the design of Mr. Richard Bach, now of Birmingham. This capstan is shown in Figs. 5 and 6, Plate 105; it consists of a vertical winding drum N for the rope, with a bevil wheel O keyed on the drum spindle; the cross shaft P, driven by the belt from the engine passing over the pulley Q, carries a sliding clutch R and two loose bevil wheels S gearing with the wheel O, by which the motion is reversed without stopping or reversing the engine.

The use of ropes and windlasses is for the purpose of suiting the new power of steam to the old implements which custom has retained, the plough, harrow, and drills; the series of operations performed by these implements when driven by steam power being identical with those previously performed. It may be questioned however whether this is the readiest or cheapest way of doing the work. The cost of ploughing by horses may be stated at 6*s.* to 8*s.* per acre. On the other hand ploughing

by steam is now being performed by Mr. Fowler at 8*s.* per acre, and Mr. Smith has stated the cost by his method to be 8*s.* 4*d.* per acre, allowing 25 per cent. for wear and tear; moreover in the variable climate of this country where seed time is the most precarious in the year, it is a great object to make use of every moment of fine weather to get the preparatory operations completed, and this forms the chief argument in favour of steam ploughing.

In Class IV—portable engines driving implements by means of endless ropes—a method of employing an endless rope has been proposed by Mr. Fisken, which is shown in Fig. 7, Plate 105. A hemp rope T passing over the engine driving pulley or flywheel U is carried round a pulley V at the opposite end of the same headland, then round the windlasses W and X at the top and bottom of the furrow to be ploughed, and back again round the windlass W, the pulley Y, and the first pulley V, to the driving pulley on the engine, where the two ends of the rope are joined. The pulleys and windlasses are thus all connected by one endless rope, by which they are simultaneously put in motion; a light hemp rope is found sufficient, very little power being required and every part being made light. The plough carriage Z is attached to a wire rope worked off the windlasses W and X, the motion being reversed at the end of each course by a reversing clutch on the plough carriage; two sets of ploughs may be readily used, or any other implement may be attached to the wire rope. The windlass carriages W and X are moved forwards by the driving rope, which remains always the proper length, the engine being stationary for the time.

A plan has also been proposed of working rotary cultivators by endless ropes from portable engines, which with the above system would doubtless be a step of great value. The ready application of an ordinary portable engine by simply passing a rope round the driving pulley, the convenient method of ploughing, cultivating, grubbing, or carting, in every portion of the field, are advantages attending this mode of using an endless rope; the arrangements moreover are mechanical, and the loss of power small. On the other hand, the disadvantages of all windlass and rope systems are, the wear and tear of the rope from trailing on the ground, the delay in adjusting the plough for each course and reversing the frame, and also the dead weight of rope to be drawn and the consequent friction upon the ground and at the windlasses.

Class V—locomotive engines working spades and other digging implements—is the most unmechanical of the classes, and far from being perfected in the details. Of the plans deserving of notice, one has a series of spades, made to enter the ground by a vertical motion, and then to throw off the soil by a horizontal motion: another has a series of spades, forks, or cutters, fixed on an endless chain working over rollers; these are pressed into the ground, and throw or turn the soil at the time only of leaving the ground. In another plan, a number of diggers rotating on their axes are pressed into the ground by the frame in which they are fixed; when at the desired depth they are turned partially round and lifted, and a semirotary motion is given to them about an axis in the frame to throw the soil. These plans however are not at present in actual use. The ultimate employment of digging implements is doubtful; this may be the easiest way to invert the soil, but another process is required to pulverise it.

In the foregoing investigation of the subject, the writer has been desirous to trace the progress of the application of steam power to the purpose of cultivation; and, without advocating any particular principle, since present experience on the subject is not yet extended enough for arriving at a final opinion, he has endeavoured to analyse and compare the several plans and processes, so as to aid in the deduction of some definite principles upon which to proceed in the further practical development of this important subject.

In concluding the present paper it may be well to take the opportunity of giving a few additional particulars that have been asked for since the circulation of the first paper amongst the members, relative to the details of construction and working of the slide valves of the portable engines described in that paper, and the comparative evaporation of water in the experimental trials of the engines there given. In illustration of the latter point the writer has brought to show a simple portable apparatus, which he has found convenient for measuring the evaporating power of different kinds of fuel.

Several modifications of the slide valves are shown in Figs. 8 to 15, Plate 106. The valves are all shown in the full port position, the dotted lines indicating their position in the middle of the stroke. Fig. 8

represents the ordinary single slide valve and slide face. Fig. 9 is a double slide valve, formed by two single slide valves modified to admit of a reduction in the length of the ports. Fig. 10 is a similar arrangement with very short ports. Fig. 11 is another plan of a single valve having a bridge on the inside. Figs. 12 to 15 show slide valves with back cut-off valves; but these four may be used with or without the back cut-off valve. These are all the kinds of valves in use in portable engines, as far as the writer is aware. Different makers hold different opinions on the subject: the back cut-off valve has certainly shown a higher duty than the single valve in the same engine; but the writer does not believe that there is so much gain in the long valves and short passages as has been sometimes attributed to them; he considers the extra power required to move them is fully equivalent to the loss from the expanded steam in the longer ports, the more so as the cylinders themselves are but short.

With the slide valves shown in Figs. 8, 9, and 10, the points of distribution of the steam are as follows, the valves having no lead, and the stroke of the piston being 12 inches :—

Steam admitted	0 per cent. of stroke.
„ cut off	79 „ „ „ „
Exhaust commences	96 „ „ „ „
„ closes	96 per cent. of return stroke.

With the valve shown in Fig. 11, with $\frac{1}{2}$ inch lap and $\frac{1}{16}$ inch lead, the following are the points of distribution, the stroke of the piston being 12 inches :—

Steam admitted	2 per cent. before stroke.
„ cut off	83 per cent. of stroke.
Eduction port opens	92 „ „ „ „
Exhaust commences	98 „ „ „ „
„ closes	92 per cent. of return stroke.

The valve shown in Fig. 9 gives the indicator diagrams shown in Fig. 21, Plate 61, (Proceedings, July, 1856,) the full line being from a valve with $1\frac{1}{4}$ inch lap, and the dotted line from the same valve with $\frac{3}{4}$ inch lap. Fig. 15 shows the slide valve of the engine from which the diagrams in Fig. 22, Plate 61, are taken.

The slide valve shown in Fig. 15 with back cut-off valve belongs to an engine with cylinders $8\frac{1}{2}$ inches diameter and 12 inches stroke, doing duty as an 8 horse power engine on the dynamometer. With the steam acting as represented by the dotted line in Fig. 22, Plate 61, the engine ran for 3 hours $27\frac{1}{2}$ minutes, or 3·46 hours, with 112 lbs. of Welsh coal, giving a consumption of 4·05 lbs. of coal per horse power per hour; the quantity of water evaporated was 1148 lbs., or 10·25 lbs. of water evaporated by 1 lb. of Welsh coal. With the valve slightly altered, giving the full line in Fig. 22, Plate 61, the engine ran for 3 hours 10 minutes, or 3·17 hours, with 112 lbs. of Welsh coal, doing duty as before as an 8 horse power engine, giving a consumption of 4·42 lbs. of coal per horse power per hour; the quantity of water evaporated was 1120 lbs. or 10·00 lbs. of water evaporated by 1 lb. of Welsh coal.

In another experiment with an engine with cylinders $7\frac{3}{4}$ inches diameter and 12 inches stroke, having the slide valve shown in Fig. 10, the engine ran for 2 hours 34 minutes, or 2·57 hours, with 112 lbs. of hard Yorkshire coal, doing duty as an 8 horse power engine, giving a consumption of 5·45 lbs. of coal per horse power per hour; the quantity of water evaporated was 868 lbs., or 7·75 lbs. of water evaporated by 1 lb. of hard Yorkshire coal.

In these experiments both the boilers were exactly alike; and the result is therefore that the evaporating power is 10·00 lbs. or 10·25 lbs. with Welsh, and 7·75 lbs. with Yorkshire coal.

With a view of further investigating this point, the writer tried several samples of coal by means of a simple apparatus for determining the heating power of coal, recently brought out by Mr. Jonathan Wilkinson of Grimesthorpe near Sheffield. The apparatus consists of a cylindrical glass jar or vessel, about 6 inches diameter and 20 inches high, which is filled with a certain quantity of water; a smaller metal jar or furnace, containing the sample of fuel to be tested, is then placed on a stand at the bottom of the glass jar, being covered by an inverted receiver or condenser, so as to exclude the water from it; a small tube rises from the condenser above the surface of the water, provided with a stopcock, by opening which the air escapes and the water is admitted to the furnace when the combustion is ended.

It is assumed that the latent heat of steam is 967° Fahr.; and also that coal burnt in oxygen evolves the same amount of heat as when perfectly burnt in atmospheric air. The latent heat of steam being 967°, it follows that if 967 parts of water are heated one degree, the same amount of heat has been employed as would have evaporated one part of water from 212°; and similarly if 967 parts of water have been heated 10 degrees, sufficient heat has been expended to evaporate 10 parts of water from 212°, and so on; the thermometer indicating the number of parts of water capable of being evaporated by the heat that has been given off. If therefore one grain of coal is burnt in the midst of 967 grains of water, it is evident that the degrees of heat acquired by the water will represent the number of grains of water which one grain of coal is able to convert into steam from the boiling point; and substituting pounds for grains the evaporative value of the coal is expressed in the ordinary manner.

The testing apparatus is accordingly made to use 30 grains of coal, and a corresponding quantity of water, that is, $967 \times 30 = 29010$ grains of water. A sample of very finely powdered coal of the quality to be tested is sifted, and 30 grains of it is weighed out; a mixture of 3 parts of chlorate of potash and 1 part of nitrate of potash, well dried and finely powdered, is added to the coal and intimately mixed with it; and the whole is tightly rammed into the furnace and a lighted fusee added. The furnace is placed on the stand with the condenser over it, and is then immersed in the glass cylinder containing the water, of which the temperature has been previously noted. In a short time ignition ensues; the heat acting on the top of the condenser is communicated to the water; and the carbonic acid gas and other products of combustion make their escape at the bottom of the condenser, and maintain a circulation of the water. When the combustion is ended, the water is admitted into the condenser by opening the stopcock, after which it is withdrawn, and the temperature of the water noted; the difference of temperature is the evaporating value of the coal experimented upon. A small correction has to be made for the portion of the heat that is absorbed by the apparatus, which is nearly constant in all the experiments, and may be taken at 10 per cent. addition to the result, with very little error; the addition can be exactly ascertained if required, but 10 per cent. is found to be so near as to give the result with sufficient accuracy.

The following results have been obtained with this apparatus :—

Description of Fuel.	Lbs. of water evaporated by 1 lb. of Fuel.
	lbs.
Charcoal for foundry blacking	12·20
Charcoal—(Oak)	12·25
Charcoal prepared for electric light, very pure .	12·50
Anthracite Coal	13·00
Anthracite Coal—average of two samples . .	13·10
Hard Yorkshire Coal—(Woodhouse)	13·75
Wallsend Coal—(Yorkshire)	14·85
South Yorkshire Coal—average of seven samples	15·00
Welsh Coal	15·12
Silkstone Coal—(Yorkshire)	15·20
Gas Coal near Chesterfield—first sample . . .	15·50
Gas Coal near Chesterfield—second sample . .	16·00

From these results it appears that the evaporating power of coal does not depend so much upon its containing a large proportion of carbon, as in the case of charcoal and Welsh coal, as upon the gaseous quality of the coal. In one case, with two qualities of Yorkshire coal, a 30 grain experiment made with this apparatus was fully confirmed by a 5 ton experiment with a steam boiler; but in another instance the results did not agree, as a different sort of coal requires a different description of furnace, the coals composed almost entirely of carbon requiring less air for combustion than the gaseous coals, and consequently requiring a smaller furnace and smaller flues. The result obtained from coke, which is composed almost entirely of carbon, is low with the apparatus; whereas with a strong draught and proper furnace it would be high.

With this apparatus every kind of coal is tried under the same circumstances; the condition of the atmosphere cannot affect the result of the experiment, if the chemicals be dry; and the simplicity of the apparatus is its own recommendation.

Mr. Clift observed that the question of the application of steam power to ploughing was one of so much importance and interest that he thought it would be advisable to adjourn the discussion, in order to afford further opportunity for its consideration, so as to do justice to the subject.

Mr. Fothergill thought it would be important in the discussion to consider mainly the mechanical questions involved, rather than the particular machines that had been described, as there might be other machines deserving of consideration which might be unavoidably passed over; and with regard to any questions of originality of invention, such points were necessarily uncertain and therefore inappropriate for discussion, and he believed several plans only recently brought forward as new would be found to have been invented previously. It was desirable to be very guarded in passing any opinion on the mechanical merits of the several plans proposed; he thought however that much might be done in improving the details, since there had as yet been little opportunity of gaining experience from the results of working, so as to ascertain the modifications required in the details, the subject being at present in a state of infancy.

Mr. Fowler wished the discussion might be adjourned, to give an opportunity of considering more fully the questions that had been raised in the paper. He had been long engaged upon the subject, and had arrived at conclusions somewhat different from those given in the paper, but it required some time for sufficient consideration and preparation to explain the results satisfactorily.

The Chairman said they would be glad to receive a paper from Mr. Fowler at the adjourned discussion of the subject, giving the particulars of the results he had obtained from his experience.

Mr. Wren Hoskyns thought the discussion of the subject would be of great importance; it was one in which he had taken an active interest. He was very glad that the question was now being taken up by the Institution of Mechanical Engineers, and was sure it was one specially requiring and deserving their aid at the present time, to work out the mechanical details best adapted for applying steam power to the cultivation of the soil; this could be satisfactorily accomplished only by the combined efforts of many minds and numerous persevering trials. How far the ploughshare was the most suitable for this purpose, opinions would vary much upon light and upon heavy land; it might be applicable to the light soils of some other countries, though unsuitable, as he

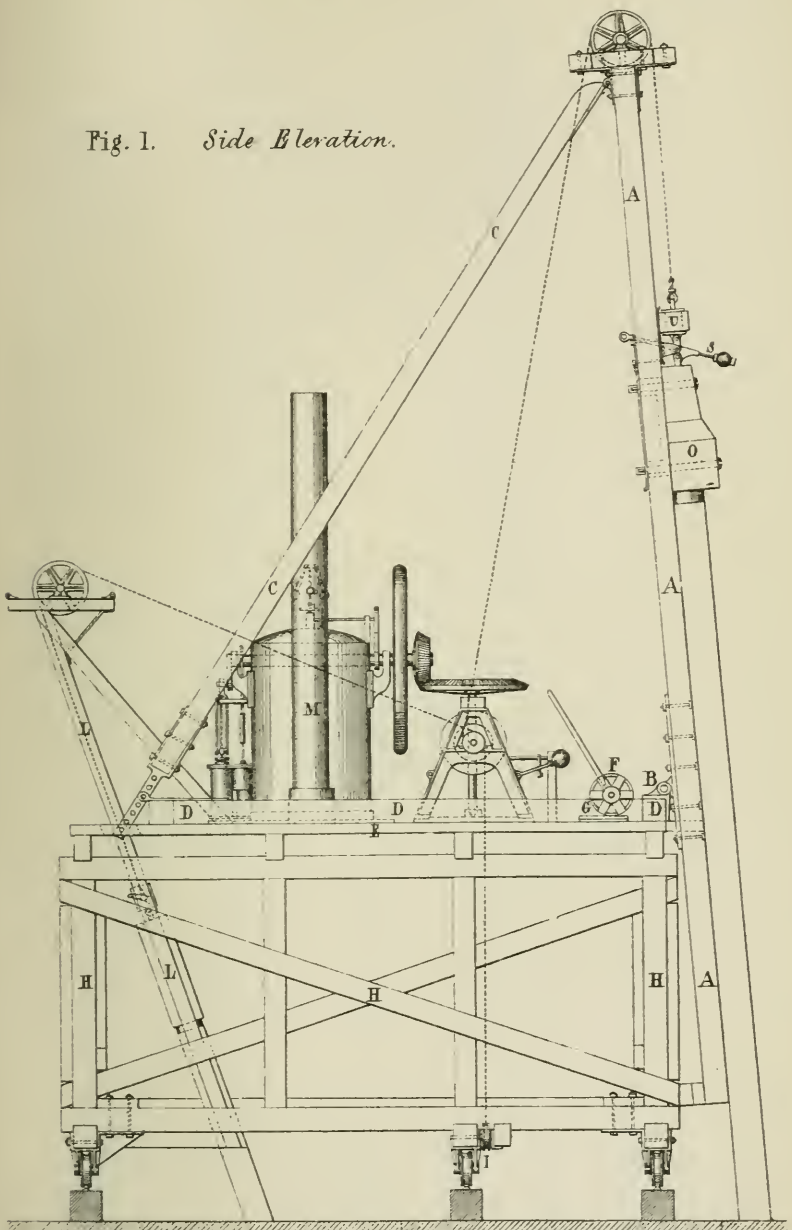
considered, for the stiff clayey soils of this, where its universal adoption was derived from original use on open light soils in the east, requiring little force to turn them over and differing widely in tenacity and in other circumstances too special to detail at present from those to be dealt with in this climate.

The CHAIRMAN proposed a vote of thanks to Mr. Waller for his paper, which was passed, and adjourned the discussion to the next meeting.

Mr. WALLER then exhibited at work the apparatus for measuring the evaporating power of different kinds of fuel.

The Meeting then terminated, and in the evening a number of the Members and their friends dined together according to the annual custom, in celebration of the Tenth Anniversary of the Institution.

Fig. 1. *Side Elevation.*

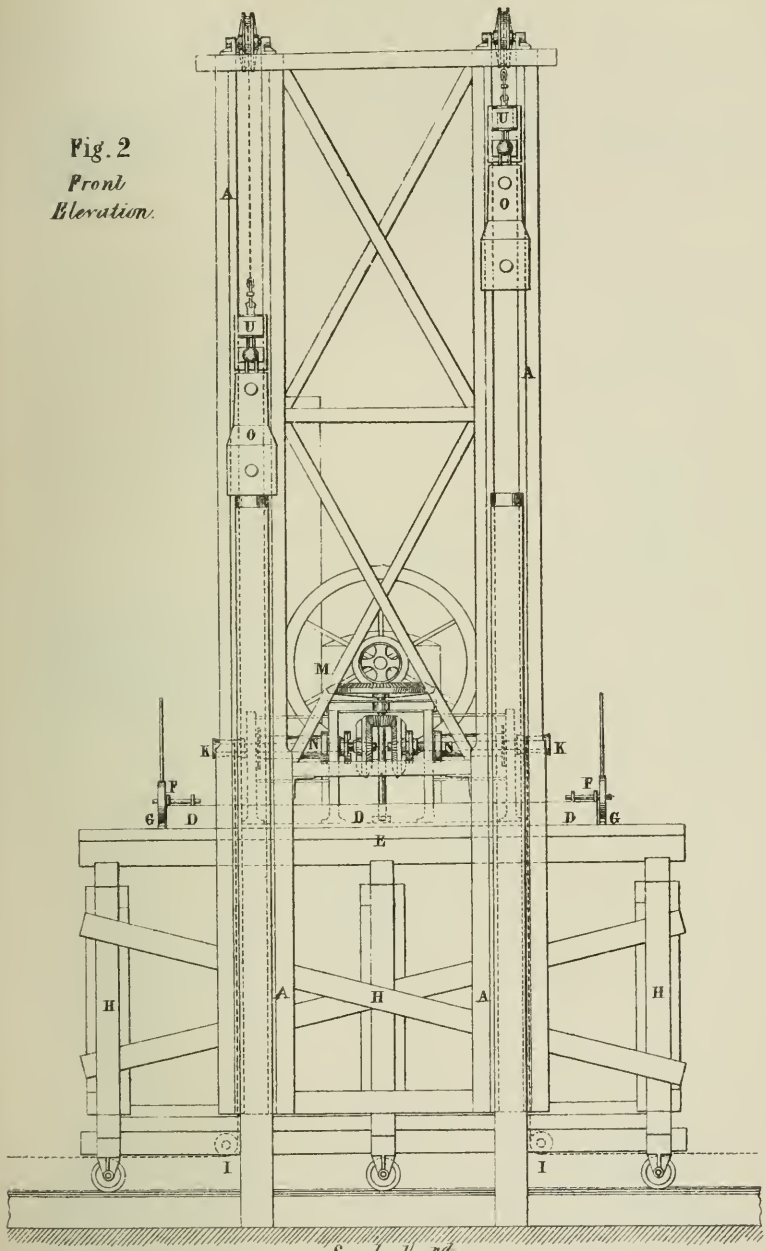


(Proceedings Inst. M. E. 1857. Page 18.)

STEAM PILE DRIVER.

Plate 98.

Fig. 2
Front Elevation.



Scale 1/72nd.

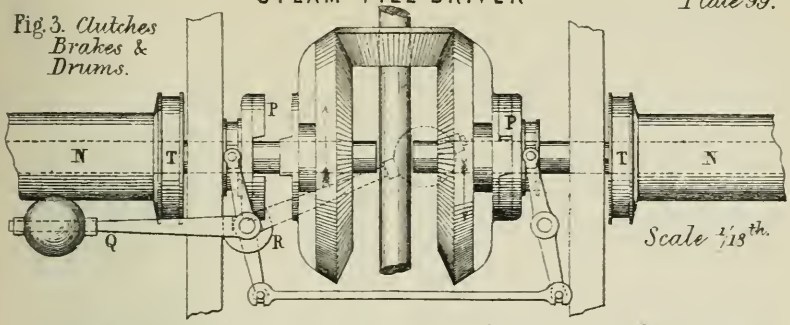
0 1 2 3 4 5 6 7 8 9 10 15 20 Feet.

(Proceedings Inst. M.E. 1857 Page 18.)

STEAM PILE DRIVER

Plate 99.

Fig. 3. *Clutches Brakes & Drums.*



Scale 1/18th.

Fig. 4. *Vertical Section of Spring Cylinder.*

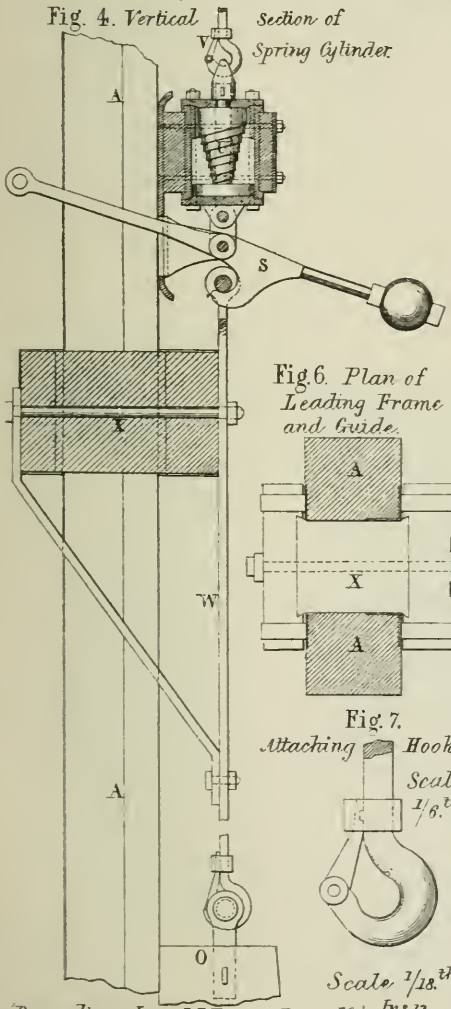


Fig. 5. *Front Elevation.*

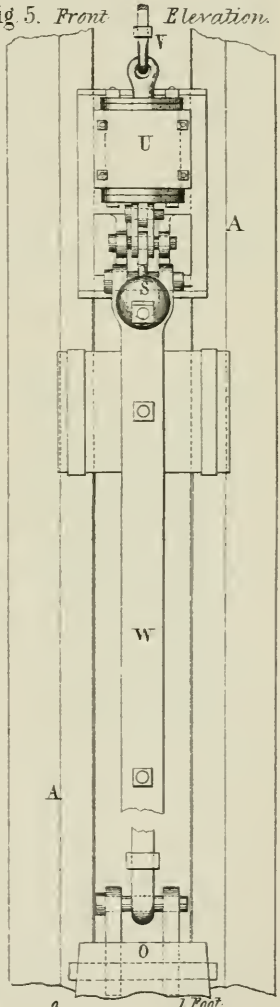


Fig. 6. *Plan of Leading Frame and Guide.*

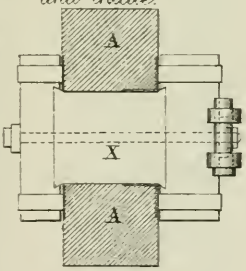


Fig. 7. *Attaching Hook.*

Scale 1/6th.

Scale 1/18th.

Ins. 12 ... 6 ... 0 1 Foot.

Fig.1. *Vertical Section of Charcoal Heap.*

Scale 1/100th.

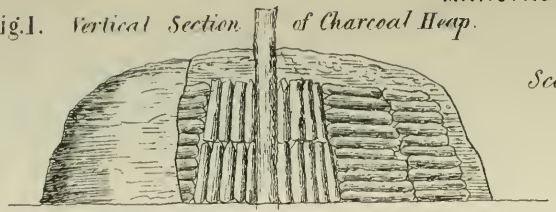


Fig.2. *Longitudinal Section of Charcoal Mound.*

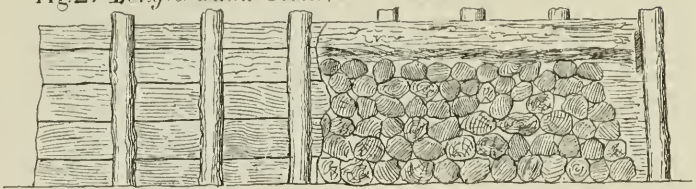
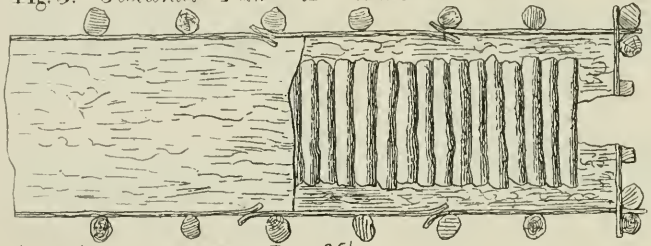


Fig.3. *Sectional Plan of Charcoal Mound.*



(Proceedings Inst. M.E. 1857. Page 25)

Fig.4. *Vertical Section of Coke Heap.*

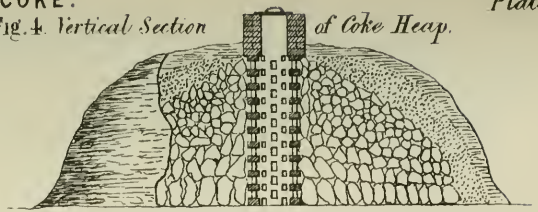


Fig.5. *Longitudinal Section of Coke Mound.*

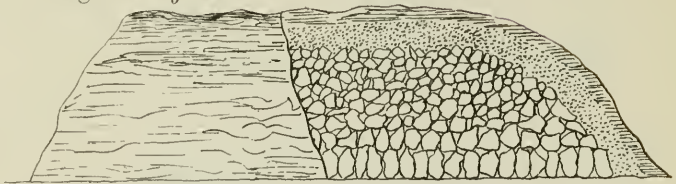


Fig.6. *Sectional Plan of Coke Mound.*

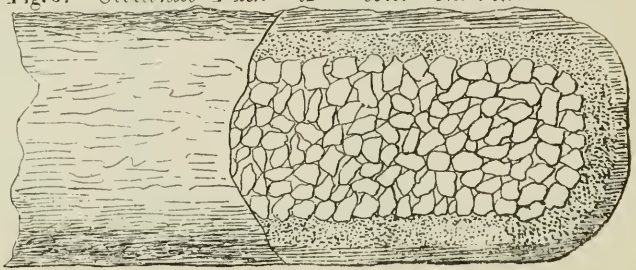
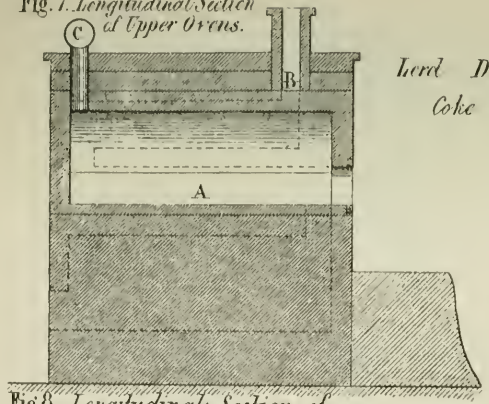


Fig. 7. *Longitudinal Section of Upper Ovens.*



Lord Dundonald's Coke Ovens.

Fig. 9. *Transverse Section.*

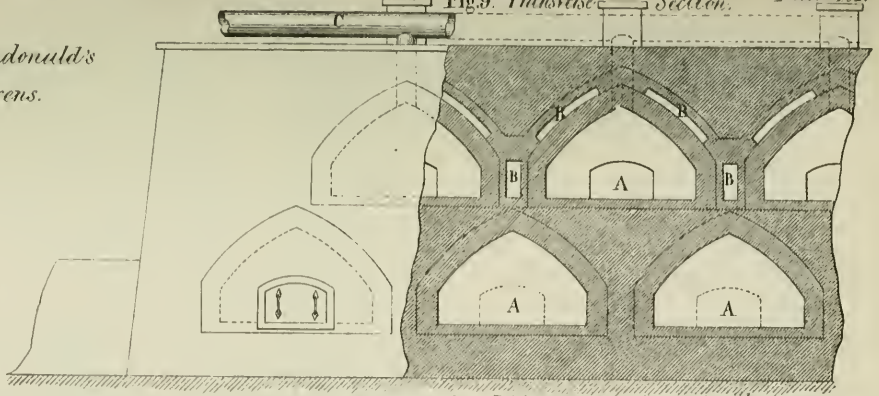


Fig. 8. *Longitudinal Section of Lower Ovens.*

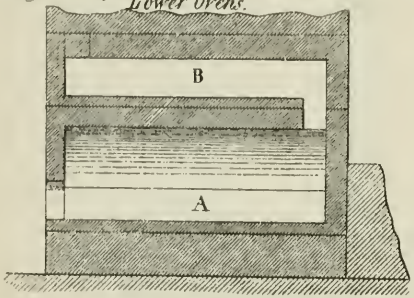


Fig. 10. *Vertical Section of Hemispherical Coke Oven.*

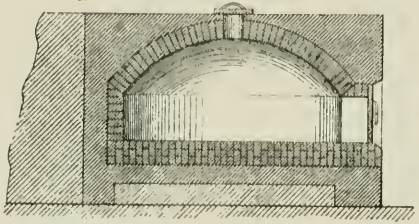
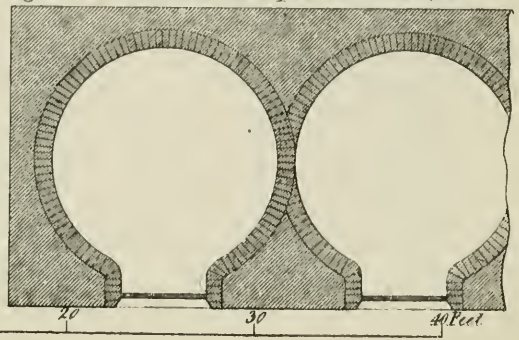


Fig. 11. *Sectional Plan of Hemispherical Coke Ovens.*



(Proceedings Inst. M. E. 1857. Page 30)

Scale 1/120th. 0 1 2 3 4 5 6 7 8 9 10

Recent Coke Ovens for Coking Bituminous Coal.

Fig. 12. *Sectional Plan.*

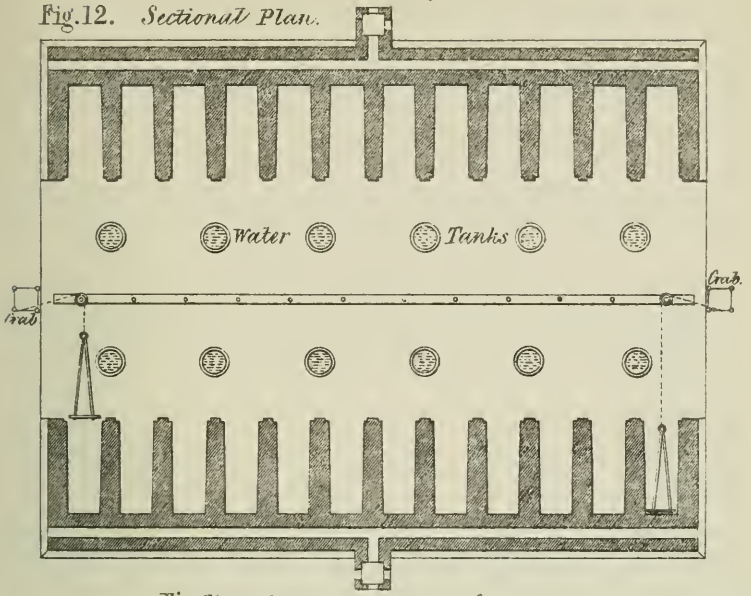


Fig. 13. *Front Elevation of Ovens.*

Fig. 14. *Front Elevation Enlarged.*

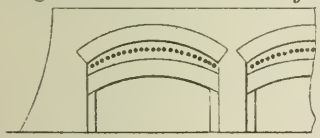


Fig. 15. *Longitudinal Section.*

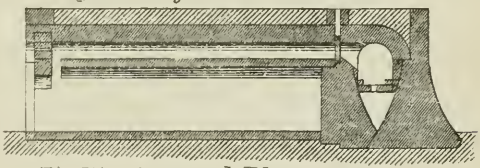


Fig. 16. *Transverse Section*

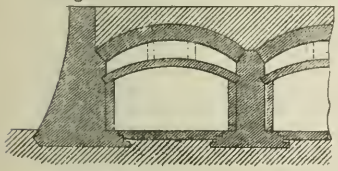


Fig. 17. *Sectional Plan.*

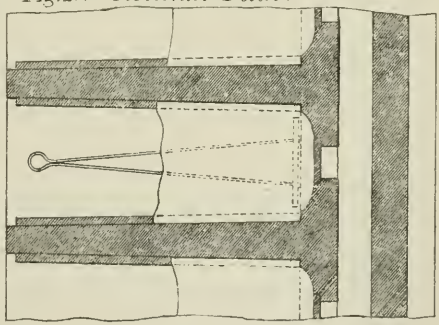


Fig. 18. *Plan of Cradle*

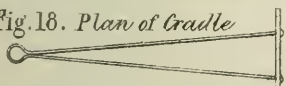


Fig. 19. *Side View of Cradle.*

Scale 1/100th. 0 1 2 3 4 5 6 7 8 9 10 15 20 Feet.

Proceedings Inst. M.E. 1857. Page 307

Fig. 20. *Side Elevation of New Coking Kiln.*

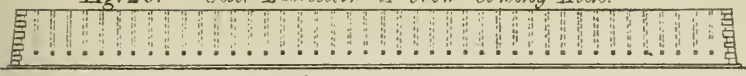


Fig. 21. *Plan.*

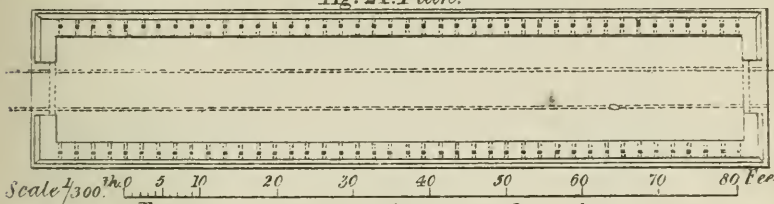


Fig. 22. *Transverse Section Enlarged.*

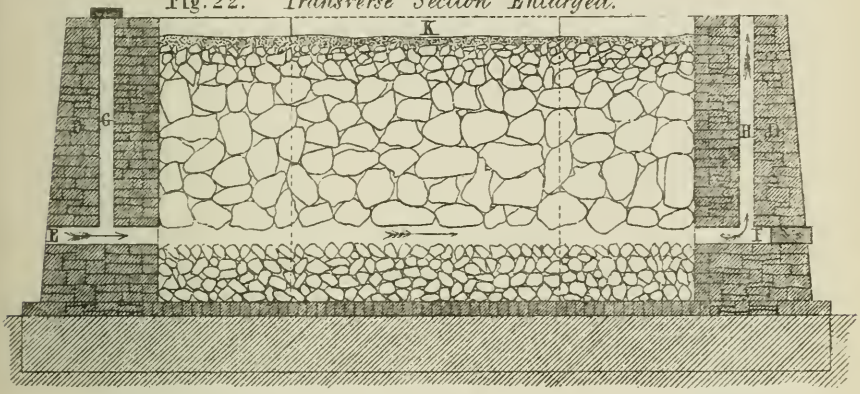
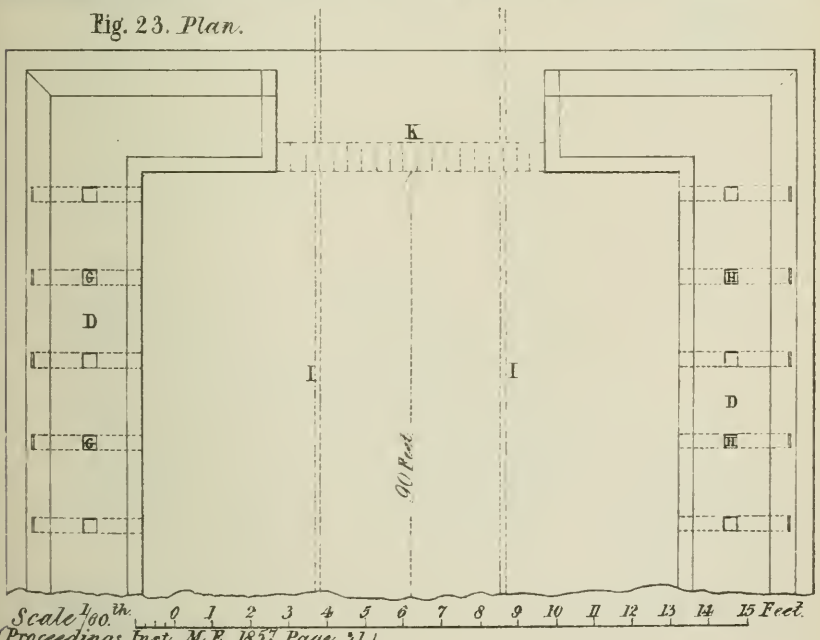


Fig. 23. *Plan.*



(Proceedings Inst. M.E. 1857. Page 31)

Wheel with Endless Railway.

Fig. 1. *Side Elevation.*

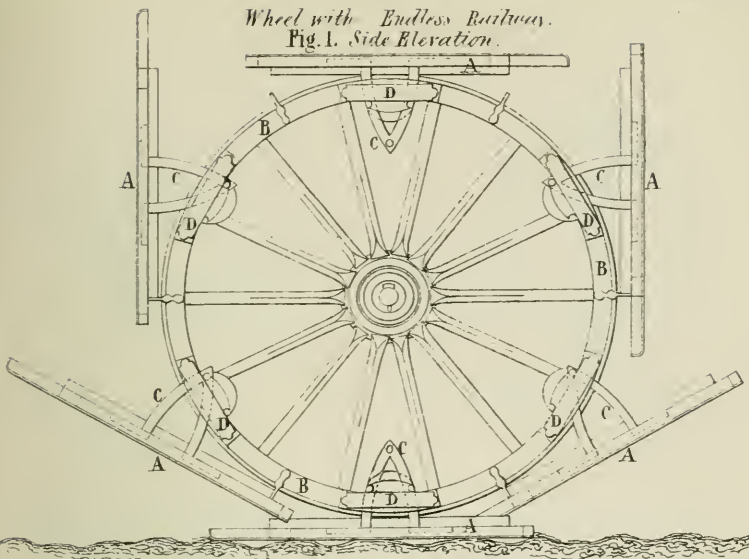


Fig. 2. *Plan*

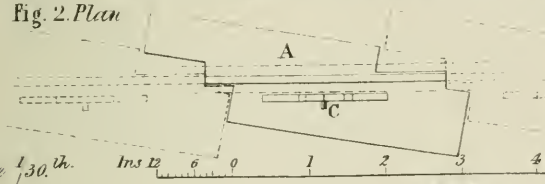
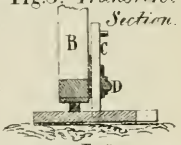


Fig. 3. *Transverse Section.*

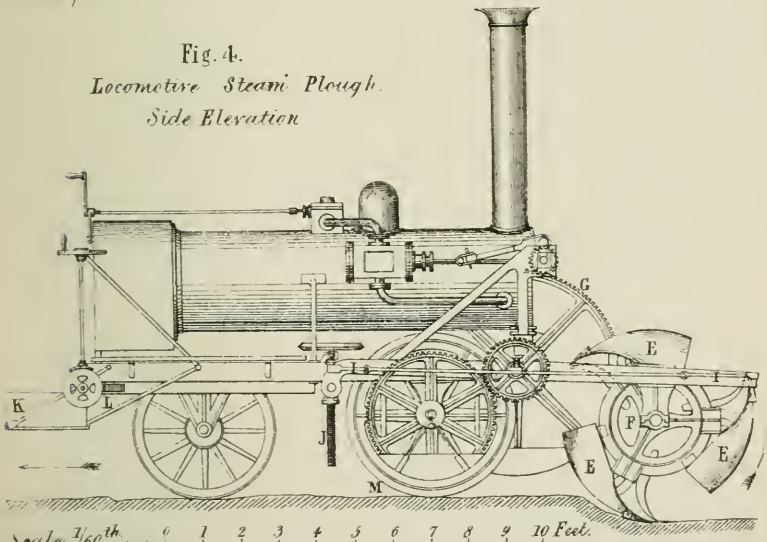


Scale 1/30th. Ins 12 6 0 1 2 3 4 5 Feet.

Fig. 4.

Locomotive Steam Plough.

Side Elevation



Scale 1/60th. 0 1 2 3 4 5 6 7 8 9 10 Feet.

(Proceedings Inst. M. E. 1857. Page 43.)

Capstan for Steam Ploughing

Fig.5. *Side Elevation.*

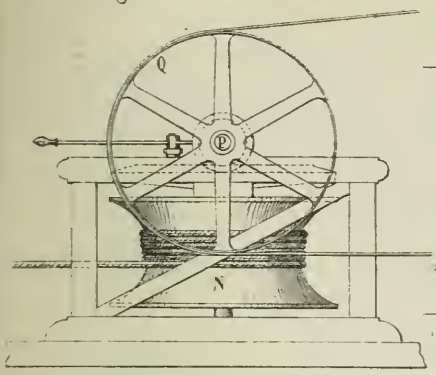
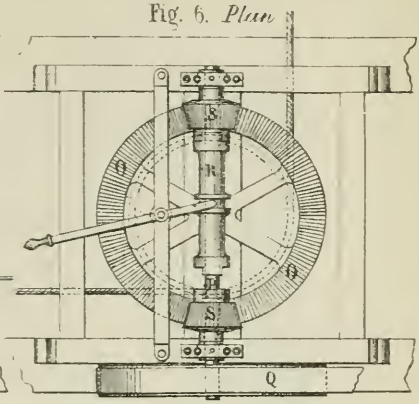


Fig. 6. *Plan*



Scale 1/30th. Ins. 12 6 0 1 2 3 4 5 Feet.

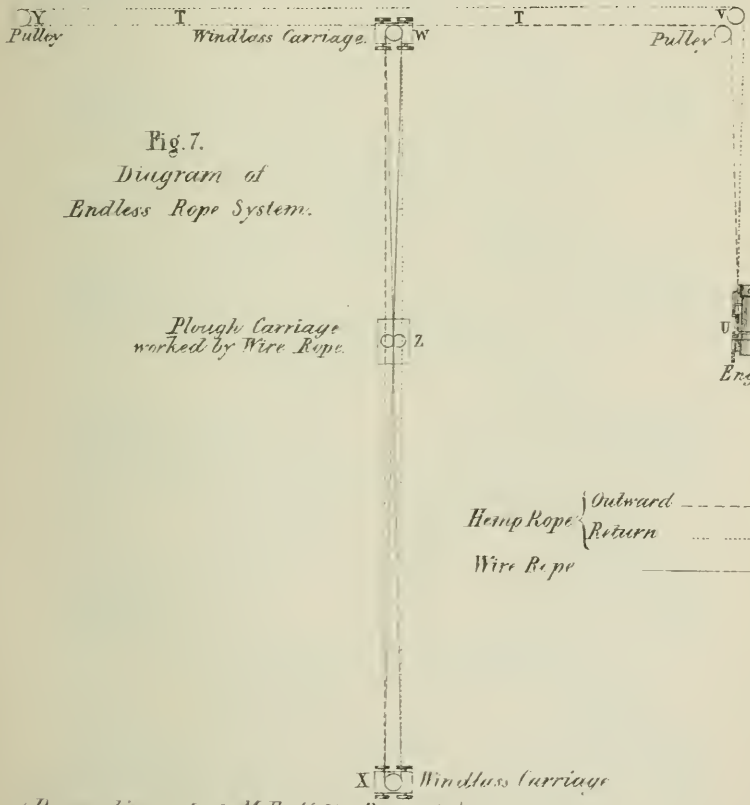


Fig.7.
Diagram of Endless Rope System.

(*Proceedings Inst. M.E. 1857. Page 46*)

Slide Valves of Portable Engines.

Fig. 8. *Single Slide Valve.*

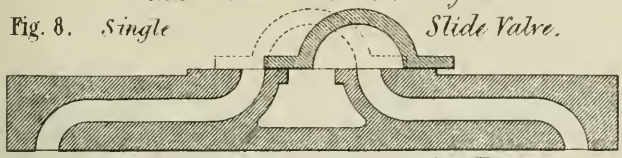


Fig. 9. *Double Slide Valve.*

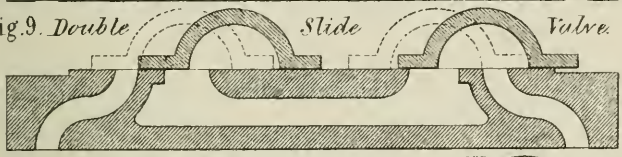


Fig. 10. *Double Slide Valve.*

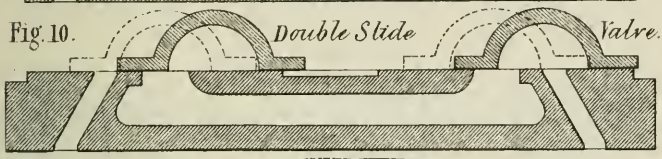
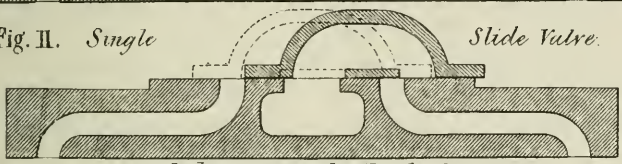


Fig. 11. *Single Slide Valve.*



Slide Valves with Back Cut-off.

Fig. 12.

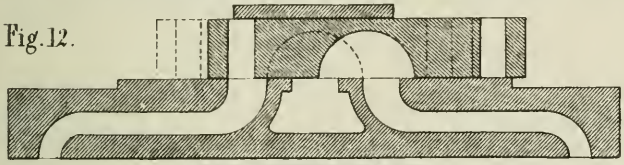


Fig. 13.

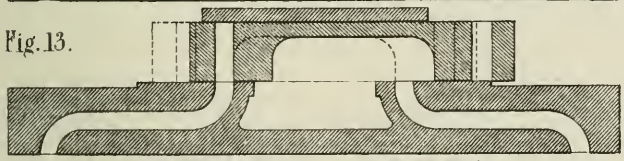


Fig. 14.

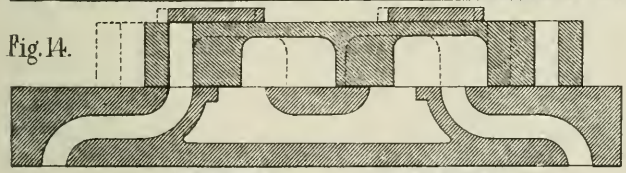
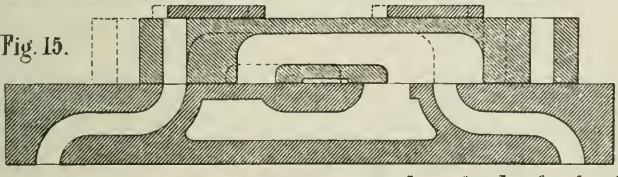


Fig. 15.



(Proceedings Inst M.E. 1857. Page 48) Scale $\frac{1}{16}$th. 0 1 2 3 4 5 *Ins.*

PROCEEDINGS.

29 April, 1857.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 29th April, 1857; Joseph Whitworth, Esq., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected: —

MEMBERS.

Joseph Cabry,	Dublin.
Theophilus Criswick,	Merthyr Tydvil.
George Dove,	Newcastle-on-Tyne.
John Fowler, Jun.,	London.
S. Wilfred Haughton,	Dublin.
John Inshaw,	Birmingham.
John Hodgson Jones,	London.
William Kendall,	Newcastle-on-Tyne.
Armand Masselin,	Westbromwich.
Walter May,	London.
William Menelaus,	Merthyr Tydvil.
William E. Metford,	Calcutta.
Frederick William Mowbray,	Bradford.
Alexander Samuelson,	Hull.
Martin Samuelson,	Hull.

George Thomas Selby, . . .	Birmingham.
Robert Cooper Sinclair, . .	Birmingham.
Josiah Timmis Smith, . . .	Dudley.
William Smith, ...	London.

HONORARY MEMBER.

William Hawkes, ...	Birmingham.

An abstract was then read of a Paper, "On the Application of Steam Power to Agricultural Purposes—Field Implements," by Mr. William Waller, of Lincoln, the discussion of which had been adjourned from the last Meeting (see Proceedings, January, 1857).

The following Paper, by Mr. John Fowler, Jun., of London, was then read :—

ON STEAM CULTIVATION.

In the present paper on the application of Steam Power to the Cultivation of the Soil, the writer purposes confining himself to the results of his own practice and the means by which it has been arrived at. In order however to treat the subject satisfactorily, it will be necessary to sketch briefly the history of another invention, the Draining Plough, to which he owes the experience that has enabled him to carry out successfully the application of steam power to the surface of the soil.

In the autumn of 1849 the writer's attention was drawn to the great expense of laying drain tiles in the ground, and he determined to endeavour to substitute machinery for the manual operation. Having once seen a drawing of a plough which was used to make a hole in the soil for the purpose of draining, there appeared no difficulty in making the same machine draw in some material to be left in the hole thus made, to form the drain. This idea was afterwards found to be not new, Mr. Saul of Garstang having proposed it in the Gardener's Chronicle some years previously. It is not necessary to detail all the various experiments that occupied the first six months of an inventor's novitiate. All the tackle that could be procured was far too weak to answer the purpose. Chain and hemp rope were tried, but when strong enough were found to be of so great a weight as to render moving about impracticable. Recourse was then had to wire rope, and in July 1850 the writer was able to bring before the Royal Agricultural Society at their meeting at Exeter a machine that would bury drain pipes made of wood to the depth of 2½ feet. The machine consisted of a draining plough, attached to a moveable windlass, by which it is dragged forwards. The windlass is mounted on rollers, and worked by horses going round and round, giving motion to a vertical shaft, on which is a small bevil wheel driving a large winding pulley on a horizontal shaft. A rope laid out along the line of the drain to be cut passes once round the winding pulley, being anchored at the head of the drain, and tightened by any convenient means at the other end. The windlass thus winds itself along the rope, the

horses walking up the field in a series of eccentric circles, or more properly a spiral. The plough consists of a straight beam of iron mounted on rollers, carrying a vertical coulter or knife with a round or square mole or pointed shoe fixed on the bottom of it, the coulter passing up and down through the iron beam so as to be adjusted to the required depth of the drain. The coulter was dropped into a hole at one end of the drain to be cut, and the drain pipes threaded on a rope attached to the shoe or mole; as the plough progressed they were pulled into the drain, the rope being detached from the shoe and drawn out again when the drain was finished.

The great inconvenience in adjusting the winding rope to the length of the field, the difficulty in keeping it tight enough to cause sufficient friction on the winding pulley, and the wear and tear caused by the friction, led to the abandonment of this plan of windlass at once, and resulted in the adoption of the windlass shown in Figs. 1 and 2, Plate 107. This is still the most convenient form of windlass for applying horse labour to heavy field operations, such as the removing of cannon or stores over a difficult country; it is at the present time being employed in pulling down trees in Whichwood Forest in Oxfordshire, with considerable saving of labour. When at work, the plate of iron A, hinged on the back of the bed plate B, is dropped into a hole dug in the ground, as shown in Fig. 1; the strut C is put up against the bracket D, which supports the vertical shaft E of the winding drum F, the bottom of the strut being chained to the anchor plate A so as to hold the windlass in an upright position. The winding drum F is worked by horses by means of the arms G. When requiring to be removed, the horse shafts H are lifted, the chains I are attached to the back corners of the bed plate B, and the chains on the winch K to the front corners; the front chains are then wound up on the barrel of the winch K, and the machine is raised from the ground, as in Fig. 2, ready to be moved. Two men in five minutes can easily do this work, and when properly fixed the windlass is capable of resisting all the power of 4 horses with a leverage of 20 to 1.

The draining plough in the meantime had undergone some alterations, and assumed the form shown in Fig. 3, Plate 108.

The beam A had been lengthened and trussed, and the coulter B carrying the mole or shoe C was adjusted to the required depth by a ratchet and pinion worked by a screw and worm wheel D. Experiments had shown the ease and accuracy with which ordinary earthen tiles could be laid, which had previously seemed doubtful; and in the spring of 1851 the plough was perfectly competent to perform drainage on good cutting clay soils, in some cases to 4 feet deep, as shown on Wormwood Scrub near London. But the principal fact demonstrated as bearing on the present subject was the practicability of managing great lengths of wire rope in a field with ease, the plough being often drawn a quarter of a mile from one fixture of the windlass. With the exception of mounting the plough on wheels instead of rollers, and locking the hind wheels backwards and forwards, preserving the upright position of the coulter, no other alteration of importance was made until 1853, when it was determined to apply steam power to the draining plough.

The first attempt was by combining engine, windlass, and plough in one carriage adapted to travel over the land, winding itself along towards a fixed anchorage, the windlass being placed in front and driven by gearing from the crank shaft of the engine, while the plough was attached behind. But the great weight on hilly land and the impossibility of managing such a large machine in the field rendered it impracticable, and it was accordingly abandoned at an early stage.

The writer then determined on fixing the windlass and engine in one corner of the field, as shown in Fig. 4, Plate 110, passing the winding rope A along the headland and round a pulley B anchored at the head of the drain to be cut; a smaller rope C was passed round a pulley D at the bottom of the field, which was unwound as the larger rope A was wound up, and afterwards pulled the larger rope and plough back when the drain was finished. This worked very well, and at once proved the perfect feasibility of applying steam power to the ordinary purposes of cultivation, as exhibited at the Lincoln meeting of the Royal Agricultural Society in 1854; this conclusion was evident to many, and called forth the following remarks from the judges in their report:—"The trial of these

immense implements could not fail to awaken much interest in our minds. A small 6 horse engine with comparative ease performed the work of 150 horses, drawing so regularly that no oscillation was observable. 'Surely,' was our remark, 'this power can be applied to more general purposes.' We earnestly commend this idea to our engineers and mechanists."

An improved mode of anchorage was now necessary, as draining in summer time to a great depth requires great power; and the former means of anchoring, shown in Figs. 5 and 6, Plate 108, was very inefficient. The following plan, shown in Figs. 7 and 8, Plate 107, was after repeated experiments hit upon. A hole is dug in the ground about 6 feet long by 3 feet deep and 15 inches wide, and two boards L and M hinged together back to back are dropped into it; the draft chain N is attached to the hind board L above the hinge, and when pulled by the draft forces the boards open in the hole, and presses them against both sides, giving a very firm holdfast capable of resisting a pull of 10 tons.

The arrangement of tackle above described and shown in Fig. 4, Plate 110, with the improved anchorage at first worked well; but the size of rope necessary to bear the greatly increased strain could only be used advantageously over pulleys larger than could be moved in the field. A windlass and engine combined, moving itself along the headland, was therefore substituted, as shown in Fig. 9, Plate 110, the winding drum being placed vertically under the boiler of an ordinary portable engine, and driven from the crank shaft by an intermediate shaft with bevil gearing. The machine is wound along the headland by a drum and rope to the head of each drain, and pulls the plough by a single rope A attached direct to the plough frame without passing round any pulley; when the rope A is wound up it is pulled out again by a horse, and the windlass moved on to the next drain. This plan is the one now in use, and a drain half a mile in length has been often put in by it from one fixture of the machine.

Having thus sketched the progress of the draining plough to maturity, it will be seen that the experience thus dearly bought was

ready to render good service in the application of steam power to the ordinary cultivating plough.

The first experiments in Steam Cultivation commenced in the autumn of 1855, when the tackle was arranged as shown in Fig. 10, Plate 110, the windlass being on a separate frame and driven by a belt from the driving pulley of the engine, but otherwise differing only in strength from the windlass adopted in 1853 and 1854 for the draining plough, as shown in Fig. 4. The success of this windlass seemed certain from the first, and it is being successfully worked now, in exactly the same form as then made. The first trial of it was with a scarifier, which it worked perfectly, turning it round at the headlands with ease, this being accomplished by attaching both ropes to the front of the machine and reversing the pull on the ropes.

A means by which steam power could practically be applied to the surface of the soil having been discovered, the next step was to consider the best mode of applying that power; and the much despised plough in its different modifications seemed the most likely instrument for accomplishing this end. In using the ordinary plough, if turned in the same furrow, it will be seen at once that one furrow would be turned over to one side, and the other to the opposite side; and when worked by horses this difficulty is overcome by moving the plough some distance along the headland, returning on the opposite side of the ridge thus left between; but this plan is impracticable with steam power, as there is no means by which the plough could be moved along the headland, except by extraneous labour. The turnwrest plough, which ploughs all one way, the mouldboard being changed alternately from side to side, could be worked by steam; but except in Kent this has always been found a complicated, and, to judge by its want of success, an impracticable machine; and to combine such a number of these ploughs as would be required for steam ploughing seemed out of the question.

It became necessary therefore to devise a plough that would return in the same track, and also turn the furrow in the same direction, without involving the complications of the present turnwrest plough. In order to do this the present plan was devised,

as shown in Figs. 11, 12, and 13, Plate 109, having two sets of ploughs, one set A right handed, and the other set B left handed, attached to the same frame C, and balanced on a pair of wheels D. By this arrangement, while one set is going up the field in work, the other set is in the air, the relative position being reversed at the end of the furrow; the wheels are then locked round the swivel joint E through the distance required to set the plough into the next furrow. This is easily done by one man, who rides on the seat F on the plough frame, and locks the wheels D by means of the hand wheel G. The first experiment showed the entire success of this plan.

Another form of windlass, differing from that last described and shown in Fig. 10, Plate 110, was also necessary; for previous experience in draining had proved that the crookedness of the fields, and the angle at which it was often necessary to plough in order to render the machine generally available, rendered it essential to mount the winding drum on a vertical axis instead of a horizontal one; and it is evident that a rope will wind on an upright drum from any part of the field, but on a horizontal drum the rope must lead off always at right angles to the axis. The windlass is accordingly made with two vertical winding drums driven by the engine, as shown in Fig. 14, Plate 110; the engine and windlass are placed on one side of the field, and a rope A from each winding drum passes round a pulley or snatch block B at the end of each headland, and round another pulley C at each end of the furrow, the ends of each rope being attached to the plough frame. The anchors C adopted in this arrangement are shown enlarged in Figs. 15, 16, and 17, Plate 107, and consist simply of a cart body filled with earth, mounted on wrought iron discs for wheels, which cut into the land as the cart travels; the cart being set to travel at right angles to the line of draft of the plough forms a perfect anchor, easily moved in one direction, but forming a powerful holdfast in the other.

Thus in the spring of 1856, at the Paris and Chelmsford Agricultural Meetings, machinery was exhibited adapted to bring into use the ordinary portable engines at present employed on a farm, for the purpose of ploughing, drilling, and scarifying by steam. As shown on these occasions, the system differed from the

plan now in use only in the mode of moving the anchor carriages and of steering the plough. The anchor carriages were then moved by a separate rope passing round the pulley B, Fig. 14, in the corner of the field, and pulled by the men at the windlass when required. This is now accomplished by the main winding rope A passing round the pulley or snatch block B, which of course tends to bring the anchor carriage C and pulley B nearer together. The anchor carriage C is moored behind by a chain D to a stake driven in the ground or to anchor boards, by which it is held in its required place; and the mooring chain is lengthened any required amount by the ploughman at the end of each furrow, so that when the plough commences work at the opposite end of the field and the strain comes on the winding rope A, the anchor carriage C moves forward the required distance until the mooring chain becomes tight.

The plough was formerly steered by a man walking in front of it, with a long pole in his hand; but now the man rides on the seat F, Fig. 11, Plate 109, steering the plough by locking the wheels D by means of the hand wheel G; and so perfect is this means of steerage that he can run entirely out of the line of draft, until the rope stands at an angle of 1 in 2 to the direction of the plough, so that no accuracy is required in setting the anchors.

Fig. 14, Plate 110, accordingly shows the best known means of applying an ordinary engine already in the farmer's hands to the purpose of ploughing, where the farmer is not prepared to have the engine in any way altered. A 20 acre field may be ploughed advantageously by the above arrangement without moving the engine. This tackle however cannot be considered by any means as perfect; two anchors, two snatch blocks, an engine and windlass, and an extravagant quantity of rope, all require to be moved from field to field, and the windlass to be accurately set for the driving belt from the engine, which often has to be done on greasy clay; shifting thus becomes an expensive operation, and the tackle is liable to more contingencies than would occur with a simpler plan, besides involving a larger amount of friction and wear and tear.

If the farmer will allow his engine to be taken off its wheels when used for ploughing and put on the windlass, the engine and windlass

combined can then be moved along the headland, as in Fig. 18, Plate 110, and in the latest plan of the draining plough. The engine and windlass then form one anchor, and all that is required is one moveable anchor C at the opposite end of the field, without any snatch blocks and with much less rope, the moving of the anchor carriage C being accomplished by a subsidiary rope D, corresponding to the mooring chain D in Fig. 14, wound on a small drum on the anchor carriage, to which a slow rotation is given by a screw and worm wheel worked by the rotation of the large drum. This plan reduces the tackle in number of parts and in cost of construction, and is the best form in which it seems possible to arrange it; in making new tackle this is decidedly the arrangement to be recommended.

Having thus described the various steps which have led to the adoption of the present plans, it is only necessary now to give the results as ascertained from daily working. In the various experiments engines have been used of from 8 to 10 nominal horse power, but giving off in reality more than double the nominal horse power.

The first point to be ascertained was the speed at which the plough should travel; and experience has shown that a speed of about 300 feet per minute, or rather less than $3\frac{1}{2}$ miles per hour, is about the best speed for general purposes when steam power is employed; at this speed every effective horse power is represented by a draft of 110 lbs., or say 1 cwt.

With regard to the amount of steam power required to plough a given quantity of land, when it is considered that in ploughing the different sorts of land by ordinary horse labour a draft of from 2 cwt., as in the light land of Norfolk, up to 8 cwt. and even 10 cwt., as in the clay land of Kent, is required for each furrow or share, it will be seen that it is impossible to form deductions as to the actual amount of power expended from the mere fact of ploughing an acre of land. Some clue however may be obtained for a comparison between the performance of steam power and horse labour: for the experiments with steam power show that, at the above speed of $3\frac{1}{2}$ miles per hour,

$1\frac{1}{2}$ acres can be done by each furrow or share in a day of 10 hours in a field 250 yards long, or 2 acres in a field 400 yards long, the furrow being 9 inches wide, allowing $5\frac{1}{4}$ hours and $3\frac{3}{4}$ hours or 53 and 37 per cent. respectively for hindrances. Now with an engine which gives off by dynamometer measure not less than 24 effective horse power (such an engine as is generally supplied as a 10 horse power engine), about 20 horse power will be available on the plough, or 20 cwt. draft at the above speed of $3\frac{1}{2}$ miles per hour; for it appears from the report of the experiments at the Royal Agricultural Society's adjourned trial at Colchester last year that 18 horse power of absolute work is done by the plough with an expenditure of $21\frac{1}{4}$ horse power of the engine, although this loss by friction is now considerably reduced by more efficiently supporting the rope and by the present plan of tackle. The above 24 horse power engine will therefore exert an available draft of 20 cwt. draft on the plough, being equivalent to rather less than 12 horses, each giving off $1\frac{3}{4}$ cwt. draft at $1\frac{3}{4}$ miles per hour, which is a full amount for agricultural horses generally. The engine will thus draw 3 furrows or shares of the ordinary 4-horse single-share plough used on heavy land, or 4 shares of the 3-horse plough used on lighter land, amounting in either case to 12 horse power total draft. Therefore, $1\frac{1}{2}$ to 2 acres being ploughed in a day by each share, the work done in a day of 10 hours is $4\frac{1}{2}$ to 6 acres ploughed of heavy land, or 6 to 8 acres of lighter land.

In illustration of the actual value of a horse's power in ploughing, it may be stated that, in travelling the 11 miles required to plough 1 acre with the usual 9 inch furrow, it is proved by experience that a horse in good condition will give off a draft varying from $1\frac{3}{4}$ cwt. to 2 cwt., at a speed of about $1\frac{3}{4}$ miles per hour but varying with the condition and quality of the horse.

The daily expenses of the engine and tackle, exclusive of wear and tear, amount to about 35*s.* 6*d.*, or say 36*s.*; this gives 8*s.*, 6*s.*, or 4*s.* 6*d.* as the cost per acre, according as $4\frac{1}{2}$, 6, or 8 acres respectively are ploughed per day. The lowest cost of horse labour to perform the same amount of work would be 16*s.*, 12*s.*, or 9*s.* respectively; and the cost of ploughing by steam is therefore only half of the cost by horse labour.

The daily expenses with steam power are divided as under :—

	s.	*d.*
2 Men at 3*s.* each	6	0
2 Men at 2*s.* 3*d.* each	4	6
1 Boy at 1*s.*	1	0
Coals, from 10 to 14 cwt.	14	0
Water, fetched by 1 horse	6	0
Shifting, at 24*s.* per week	4	0
Total daily expenses	35*s.*	6*d.*

The reduction of cost however forms but a small part of the advantages offered by steam cultivation. It is found that heavy land ploughed by steam is left in an almost perfect state of tillage, as it is not the plough but the weight of the horses trampling on the land which causes that solidity of the furrow slice of which the advocates of rotary cultivation complain. This was clearly proved in Wiltshire a few weeks ago, where a piece of land ploughed by horses lay side by side with a piece of land ploughed by steam; the latter was harrowed down and sown in perfect tillage after two days' dry weather, when the former more resembled a mass of boulders than a friable soil and would require a fortnight's dry weather to render it workable. Any one who has watched the impression of his foot on the sand of the sea shore, and has seen the distance to which the water is disturbed by his weight, as shown by the colour of the sand, will appreciate the effect of a horse's weight on a wet clay soil. The increased speed of the plough tends also to produce a quicker tillage. Add to these advantages that by the aid of steam ploughing the farmer obtains a perfect command over all the heavier operations of his farm, and can plough the whole of his land during harvest; and it is not easy to exaggerate the importance of this fresh field of conquest upon which steam has just entered. The estimation in which steam ploughing is held by the farmer may be gathered from the fact, that so pleased were the farmers of Kent with the results of the first three months' working of the steam plough, that they presented the gentleman who introduced it into the county with a testimonial, towards which subscriptions were extensively contributed.

There remains now only one more subject to touch upon in this branch of steam cultivation; and that is the wear and tear of the wire rope, on which this method of steam ploughing is dependent. It is found from experience with the steam plough, and from the experience of those who are daily using wire ropes on inclines and railways, that the wear and tear varies considerably with the circumstances in which the rope is placed. Pulleys of large diameter in proportion to the size of rope, an under rather than an over strain, and proper support on rollers, make the results of number of miles worked vary from 9000 up to 110,000 miles for each rope. In the lowest returns the writer has been able to procure under the most unfavourable circumstances, a rope has worked only 9000 miles. The following table gives returns of miles worked by wire rope, from a large colliery district in the north of England; and on looking over the papers from which the returns were extracted, it was curious to observe how exactly the same circumstances produced the same results.

Table showing Number of Miles worked by Wire Ropes.

Rope No. 1	65,860 Miles.
„ 2	110,510 „
„ 3	38,262 „
„ 4	18,200 „
„ 5	18,148 „
„ 6	24,400 „
„ 7	9,700 „
„ 8	14,564 „
„ 9	12,044 „
Average	34,632 Miles.

The rope required to plough a furrow 400 yards long costs about £40; and in the new arrangement of tackle with only one anchor carriage, (as shown in Fig. 18, Plate 110,) two thirds of the rope never goes round the pulley C at all. The pulleys should never be less than 4 feet in diameter, and the rope can be easily carried entirely free from the ground. If a wire rope travels only 9000

miles with a four furrow plough, the furrows being each 9 inches wide, it will plough 3270 acres, and with a three furrow plough 2450 acres, thus costing 3*d.* and 4*d.* per acre respectively at the above price.

The writer has recently made an improvement in the manufacture of wire rope, by the introduction of one steel wire in each strand of the iron wires; the steel wire projecting from the surface of the rope will probably take the greater part of the wear. A specimen of the rope made in this manner is exhibited, and good results may be anticipated from it, though it has not yet been sufficiently tested for any definite opinions to be formed as to its durability.

Mr. Waller observed that the point he had chiefly considered in his paper was the principle of the machine for cultivation that was most suitable for the application of steam power; for this purpose he had reviewed the several systems at present engaging attention, whether in actual use or only proposed; he hoped the consideration of the subject by practical engineers would lead to some definite end, by an examination of the principles involved in the question from an engineering point of view. The question as to how far cultivation was efficiently accomplished by any plan would then lie with the farmers, by whom the success of any machine or system must be determined by the actual results obtained or the quality of the work done. He had been led to give the preference decidedly to rotary cultivators, from mechanical considerations alone, as presenting in principle the best means of applying steam power successfully to the work to be done.

With regard to the mode of communicating the power, whether by a locomotive or stationary engine, it struck him as a consideration bearing on the question, that ropes had generally been superseded by locomotive engines for the purposes of hauling on railways, and he did not see why there should be a difference in the case of agricultural implements. A step had already been taken in this direction by the introduction of the traction engine of Boydell,

which could be readily applied to all the purposes of agriculture, either as a fixed engine remaining in one place to perform the work by means of machinery put in motion by it, or as a locomotive dragging implements or moving itself from place to place without requiring extraneous labour like the ordinary portable engines. This engine when employed for agricultural purposes should, he thought, be intended as a locomotive only for drawing itself to the field and taking up its position there, becoming then a fixture and working as a stationary engine till required to move to another place, thus saving the horses required to transport the portable engines from place to place. Of the plans for working by ropes he thought the system of a single endless rope proposed by Mr. Fisken had advantages deserving attention, being a complete system in itself, and not dependent upon any particular arrangement or construction of its several parts. They were however certainly indebted to Mr. Fowler for originally suggesting the application of steam power by means of ropes, and for perseveringly and successfully carrying it out into practice. The dispensing with horses was a great point in the consideration of the subject; for unless they could be entirely superseded they were idle while steam was employed, or were used as mere auxiliaries, and the item of cost was thereby increased.

Some suggestions as to the form of the implements might be obtained from considering the form and mode of action of the mole, whose hind claws formed a complete anchor to push against in the rear, while its fore claws were made for excavating and removing the soil, their action appearing to favour the rotary principle for cultivation. Whatever plan were adopted, it was evident that the more ready and direct was the application of steam power, the more successful it would be. The first attempt to apply a rope for drawing a plough was, he believed, made in April 1849, with the capstan described at the previous meeting, designed by Mr. Bach of Birmingham, consisting of a friction capstan driven by a belt from the engine, the rope being wound on one side of the capstan and unwound from the other.

Mr. Atkins, of Chepstow, considered the subject one of great importance, and thought that the whole of even the naval and

manufacturing interests of this country were less extensive than those involved in agriculture. He had been long engaged upon the question, and had had a machine in the form of a rotary cultivator at work upon a farm in Oxfordshire as early as 1845. The primary object of cultivation was to make the soil hollow, so as to allow a free action of the atmosphere upon all portions of it, and facilitate the percolation of the water from the surface into the ground below; he had put this principle in operation by employing hollow ventilating pipes, by which ammonia and other gases were introduced into the soil, and thought much might be done by a further development of that system. The cultivating machine that he proposed for steam power was a rotary one, with rotating forks or spikes, breaking up and loosening the soil. The next question was as to the best mode of propelling the cultivating machine, whether by direct traction or otherwise; and he considered the best plan would be to have a large fixed engine of 20 or even 30 horse power, set down in the centre of a farm, driving by means of endless wire ropes extending to a great distance, and working at a high speed so as to diminish the weight of rope required, the rope being carried on standards at some height from the ground like a colliery rope. This idea had been early suggested to him by seeing a rope manufactory at Bristol, where a rope of 2 miles length had been working constantly for two years, taking the power from a 10 horse engine and driving various machines all down the walk for a mile distance. Great expense however attended the trial of any such plans on a large scale, and this difficulty proved a serious barrier to the introduction of any new systems of cultivation.

Mr. Siemens thought the construction of wire rope proposed by Mr. Fowler, having one steel wire introduced in each strand of the wire ropes, was a step in the right direction; but it would be even better if all the wires were of steel, in which case the rope would be as light again and much more durable. He had lately seen the great Atlantic cable being made at Birkenhead, and found that a few miles' length in the middle of the cable was to be of steel wire, for the sake of greater strength at the part where the laying of the cable was intended to be commenced simultaneously from the two vessels in opposite directions.

Mr. Wren Hoskyns observed that a great difficulty in practically carrying out the application of steam power to the cultivation of the soil had arisen from the imperfect communication that existed between mechanical men and those engaged in agriculture. The subject had hitherto been treated chiefly from an agricultural point of view; but there was a great difference between the mode of considering it by the agriculturist and the engineer. Agriculture and mechanics were seldom united in one person; and he therefore welcomed with pleasure the present occasion of bringing them to bear together on this subject. A person engaged in practical agriculture conducted on the ordinary system had unavoidably a great difference of idea, and more prepossession to overcome than a mechanical engineer practically engaged in designing and working machinery; there was consequently a great difficulty in the mutual communication and explanation of their ideas, the one party not being experimentally familiar with the field requirements of the case, and the other not understanding mechanical details or design.

With respect to ploughing by steam, as far as regarded the agricultural side of the question, and considering the actual results in the work performed, there could be no hesitation in saying that Mr. Fowler's plough had produced the most perfect specimens of steam *ploughing* that had yet been seen, and had proved eminently successful, obtaining economical results of great value. But when the plough was altered from the original form, as in this case, by the introduction of four shares mounted on a single frame, it was virtually a new implement in the farmer's hands, with which he was not familiar; and an implement constructed upon entirely new principles would accordingly not have to contend with greater difficulties, as regarded its recognition among agriculturists, than the plough thus modified. The main question however still remained, whether *ploughing* by steam was the most desirable object to be aimed at; and his own opinion was that a rotary cultivator would be found the most efficient means of applying steam power to cultivation. The combination of steam with machinery not properly suited to develop its power and capabilities could not prove ultimately satisfactory; and in all other cases, he believed, where steam had

been applied in place of horse or other power, it had led to an entire revolution in the apparatus or machine to which it had been applied: the iron rail had been substituted for the common road, the paddle wheel and screw for the oar, and the rotary threshing drum for the flail. Steam had thus always demanded a new tool, specially adapted to its own capabilities; and hence in applying steam power to cultivation the first experiments should be to find out machinery suited to the new power employed. But the experiments necessary for this purpose would require a life and a fortune; and the case appeared certainly a proper one to be taken up by the country, or by a united body of persons having the means of thoroughly carrying out the trials.

The primary consideration in all machines for cultivating the ground was that mere stirring or confusion of the soil was not cultivation, though sometimes thought to be so; it was found in actual farming that there must be an absolute inversion of the soil into some regular furrow kept open for that object; and consequently all cultivating machinery in which that essential was overlooked would fail in practice. The first essential was therefore that a regular furrow should be continuously kept open, into which each successive portion of the soil should be received; and a second was that there should be a proper relation between the rate of progression of the cultivator and the rate of turning over the soil, in order to effect thorough cultivation. Any simply rotary tool armed with hooks or forks would, he was confident, prove unsuccessful, as it would serve only to disturb the soil without effecting its cultivation; nor did he think rotary ploughshares likely to succeed, the form of the ploughshare being peculiarly designed for rectilinear motion. Several ingenious contrivances that had been attempted had failed from not keeping in view both the above essentials, and others from defective or injudicious mechanical construction or principle of action.

There were greater difficulties to be encountered in applying steam power to cultivation than were apparent at first sight; and having pretty well considered the subject, he felt more strongly the difficulties that had to be met before a successful issue could be arrived at; but he had no doubt of success being ultimately attained.

Mr. Fowler remarked that his object in the paper just read was only to give the history of his own experience, first in the employment of steam power for the drainage of the ground, and next in the application of the same principles to cultivation. He fully agreed with Mr. Hoskyns that it was essential to preserve a regular furrow in the process, in order to ensure a complete turning over or inversion of the whole soil, which was necessary for proper cultivation; and also to proportion properly the rate of the forward motion to that of the inversion.

The question of the applicability of the plough for the purpose of cultivation by the steam engine, or of some apparatus acting on a rotary principle as had been suggested, formed only a part of the subject; and until that question could be decided by longer experience, he thought it was requisite to arrange some efficient mode of accomplishing the object by means of such steam power as was at present available upon a farm, making use of the present common implement, the plough. The ordinary engine used on a farm was therefore tried, and it was thought at first would be suitable for the purpose; but further experience showed that a special modification of the engine was necessary, in order to reduce the complication and expense of tackle that was otherwise required in the field. The form at present arrived at was doubtless only a further advancement, to be superseded presently by something better; and he did not at all maintain that the system of compound ploughs and engine that he had adopted would be the best final arrangement, but thought it had proved the most practically successful of the plans yet adopted. For arriving at a new implement it was necessary to go forward step by step, as in every other mechanical improvement, starting at each step from what had been already established as practicable, and so advancing to what subsequently became practicable. This consideration had led him to take the ordinary plough drawn by horses as the first established point to start from, in attempting to substitute steam power for horses; and he doubted whether any attempt to jump at once to an entirely different system of cultivation, such as that of rotary machines, could be advantageously pursued, though the progress of

improvement might ultimately lead to such a change; and he hoped to see Mr. Hoskyns' plan at some time fully tried.

In reference to the question of stationary or locomotive power, he thought Boydell's endless railway would have an important bearing on the subject, though involving serious mechanical objections in construction; and would be likely to prove a valuable aid for traversing along the headland, if not for working down the field. The machine well deserved consideration and thoroughly working out in the details, and would then lead to steam power being much more extensively used in many cases where its application was at present checked by the difficulty and expense of bringing the power to the required place. If proper mechanical attention were paid to the employment of steam power, it would immediately lead to the use of larger engines with a deeper cultivation of the soil. At present he did not see why a simple low machine on the principle of the traction engine, standing only a little height from the ground, should not take the place of the ordinary four horse team, and prove perfectly practicable for general use on the farm. Such a step, with the employment of high pressure steam reducing the weight of the engine, would doubtless lead to great ultimate changes in the mode of conducting all outdoor farm operations.

As to the actual mode of cultivation by steam to be ultimately adopted, he thought it probable that two different plans would be found necessary in different parts of the country, in consequence of the differences of climate and soil; the plan that would do in the neighbourhood of London would not succeed in Devonshire, as in the one case it was particularly required to bury all the weeds, whilst in the other the land was comparatively free from weeds. However the most advisable course at present was, he thought, to adopt the plan that was already known to accomplish the object by the results of previous experience; when that first step was thoroughly made, the next would prove comparatively easy.

Mr. Smith, of Woolston, said he had been long working at the subject of steam cultivation, and had now been farming by steam for a year and a half by means of windlasses similar to those described in the paper, his original apparatus being still at work on his farm near Bletchley.

In entering upon the question of cultivation, there were three principal points to be considered:—first, what is the nature of the soil; second, what is to be understood by the tillage or cultivation of the soil; and third, by whom is the tillage to be done. With regard to the two first considerations, if any plan of cultivation was to be made to answer, it was necessary to have implements which would serve for any sort of soil that might be met with on a farm, whether light or stiff, and with an even or uneven surface; and if the implements were capable of overcoming the roughest soils, there would he thought be little difficulty with the easier ones. There had hitherto been two principal methods of tilling the ground, with the spade, and by the plough, both specially adapted to the power by which they were to be worked. When a new power was introduced it had therefore to be considered how it could be applied best, or what implements could it handle. It might be the case that some places required a different form of implement from others; but he thought that generally the implement that would do for the rough soils would suffice for the others. The results that had been obtained from the spade and the plough, in regard to the quality of the work done, should also be considered; and he believed it was generally admitted that spade husbandry had yielded by far the greater produce, and that the plough, though beautifully adapted to be worked by horses, was not to be compared with the spade in respect of the tillage it was capable of producing. It was therefore to be inferred that, instead of simply attempting to draw an ordinary plough, the new machinery to be worked by steam should imitate the spade in its action, and should dig deep down like the spade, in order to be successful. On his own farm he had accomplished a complete tilling of the soil by steam power to a depth of even 20 to 22 inches; but he recommended about 14 inches as the general depth, the object being to turn up some of the subsoil but not too much. The plan he adopted was to employ an ordinary 8 horse power portable farmer's engine, such as was used for threshing, drawing by means of wire ropes a double-mouldboard trenching plough, with two subsoil ploughs behind, the first plough making a trench about 32 inches wide, in which the subsoil ploughs followed, lifting up and turning over the subsoil to the desired depth.

To do work upon the flat, the trenching plough was taken out, and a subsoiler put in its place, breaking up the land to a depth of 6 or 8 inches, bringing all the filth to the surface. In the plough described in the paper, having four ploughshares fixed on one frame, he thought the shares could not all work to the same depth in uneven ground, and the work would consequently be irregularly done; he had seen a trial of the plough at Chelmsford, and it certainly got through the work beautifully, but he observed that the depth of the furrows turned by it varied considerably in some parts.

With regard to the third consideration, by whom the work of cultivation was to be done, whether by the farmer himself or by hire, it should be observed that if done by hire a very different system would be required, as to arrangement and extent of tackle, from that necessary in the other case. He was decidedly of opinion that every farmer must do the work for himself, in order to secure the greatest efficiency and the greatest saving of time and expense. The saving of time was particularly important, as the first fortnight directly after the bean harvest in September might be said to be worth the whole year to the farmer; the farmer must therefore plough himself, and not hire the power and implements as was advantageously done in the case of threshing and other barn operations. He found a 7 horse power engine was sufficient to do 5 acres per day, making 60 acres in the fortnight; but for the whole season not more than 400 acres could be calculated on with an engine of that power. For the average work must be reckoned at only 4 acres per day with a 7 horse power engine; and as ploughing ought never to extend beyond the middle of November, there were only 70 days left before winter, and say 30 days more in the spring, making 100 days total for the season; this at 4 acres per day gave 400 acres as the whole amount of work that could be reckoned upon from a 7 horse power engine in the season. An engine of that power ought therefore to be provided for every 200 acres, in order to obtain the full advantage of steam power. By the farmer thus doing the work for himself, he would also have steam power available for threshing corn and cutting chaff in the idle months when not required for ploughing.

He had lately exhibited the application of steam cultivation on his own farm to a number of gentlemen from different districts of the country, and they had been struck with the superior condition of the steam cultivated land compared with the portion of the same soil that was under the ordinary system, the steam cultivated part being in a much cleaner and more healthy state. The first office of steam cultivation would be to take off what might be called the pitch-plaster upon the earth's lungs, caused by the constant treading down and consolidation of the subsoil by the horses' feet, which had been going on through a long succession of years under the previous system of ploughing. He had had land that was quite filthy under the old plough system, yielding 5 quarters per acre of beans the first year upon his system; after being trenched 14 inches deep by the steam cultivator last year, a yield of 8½ quarters per acre of oats had been obtained, and the land was now clean. He found that 1 acre could be done by the steam cultivator in 1 hr. 13 mins., and by then simply passing a horse cultivator across over the surface it was rendered at once fit for use. If a small quantity of filth remained in the land after the process, it came to the surface and was removed by the action of the air or taken off by hand.

The advantages gained by the use of steam power, in superior cultivation, as well as in other respects, would be very great, and he had no hesitation in saying that steam cultivation would rapidly extend in use throughout the country.

The Chairman enquired how many of the cultivating ploughs described in the paper were at present at work, and how long they had been in regular use.

Mr. Fowler replied that there were 6 ploughs now at work, the first of which had been 8 months in use. A number more were in progress, and about 40 were expected to be in regular work in the course of a month or two.

Mr. Clift asked what would be the cost of the apparatus complete for a farm of 200 acres.

Mr. Fowler said that the cost of the apparatus complete for a farm of that size, with a 7 horse power engine, capable of ploughing 4 to 5 acres per day, would be from £400 to £500, including all

tackle; and for a very large farm the cost would be from £800 to £1000.

Mr. Hawkes stated that he had seen the trial of Mr. Fowler's compound plough at Milton, but did not notice the difference of depth in the furrows that had been mentioned; the plough was working on that occasion at a great disadvantage, ploughing across previous furrows in rough ground, and the machinery by which it was being driven was too light and often breaking down, the gearing being driven by a 22 horse power engine with steam at 80 lbs. per square inch pressure; but it was ploughing on that occasion at the rate of 12 acres per day, but stopping for repairs about every half hour.

He had also witnessed the trials referred to by Mr. Smith on his own farm, where 5 acres per day were being cultivated by a 7 horse power engine. There was certainly a striking contrast between the steam cultivated land and the adjoining land under horse ploughing, which showed that valuable results had been already realised by the application of steam power to cultivation.

The Chairman proposed a vote of thanks to Mr. Waller and Mr. Fowler for their papers, which was passed.

The following Paper, by Mr. Joseph W. Wilson, of Banbury, was then read:—

DESCRIPTION OF IMPROVED MACHINERY FOR ROUNDING, SURFACING, AND SHAPING WOOD.

The great variety of articles of a cylindrical form which are manufactured in wood, and the inefficiency of the common wood lathe in turning long lengths, the trouble and time required for keeping it in working order, and for fixing and adjusting tools for turning, surfacing, or planing wood, led the writer to endeavour to improve the machinery at present employed; and the improvements that he has made, with the results obtained from them, form the subject of the present paper.

The machine first to be described is the Rounding Machine, shown in Figs. 1, 2, and 3, Plate 111, which is in use at the Timber Works, Banbury. The timber A to be rounded is prepared for the machine by being sawn into a rectangular form of any required length. It is fed through the grooved self-acting weighted rolls BB, which advance it towards the revolving face plate C, on which the rounding tools D E are fixed. When rounded, it passes through the wrought iron casehardened die F, which keeps it perfectly steady for the cut: in this manner it passes through the tubular headstock G, to which the face plate C is attached, and is then taken between two endless chains HH which pass over wheels and rollers, and are impelled in the same direction as the feeding rolls BB, and at the same speed. The links of the chains are hollowed out and lined with leather to preserve the finished wood from any impress. The chains are weighted, and are for the double purpose of pulling the tail end of the wood through the die F after it leaves the feeding rolls B, and keeping it from turning round, which the friction and slight compression during its transit through the die are likely to cause it to do at that time.

In rounding hard woods, the friction in the die is much increased; and the heat thus generated is dispersed in the following manner. A tubular receptacle constantly supplied with compressed air, the

temperature of which is lowered as much as possible, is connected with the rounding machine by a small pipe, and a constant stream of air is allowed to play upon the die; this by its expansion absorbs a large amount of heat from the overheated die.

Figs. 4 and 5 are a side elevation and front view enlarged of the face plate C, showing the form and position of the rounding tools, which consist of a cylindrical gouge D, and a paring tool E in the shape of a disc of steel with one bevilled edge. At the commencement of the writer's experiments the face plate was supplied with a set of gouges and chisels of the usual form, lapping over the work as in the ordinary turning of soft woods; by this arrangement only one portion of the edges of the gouges and chisels acted upon the wood, and it was found that after paring 7680 feet of circumferential length, or producing only 80 feet run of rounded wood, they required to be taken out, sharpened, and reset, involving a great waste of time and steel. By the use of the new cylindrical gouge D and paring disc E these difficulties have been completely obviated by the writer. Figs. 4 and 5 show the position of the tools and the manner in which they are fixed on the face plate C; the gouge D, which is placed a little in advance of the paring disc, is 2 inches internal diameter, and is sharpened from the outside; it is held in a strong wrought iron standard I, which admits of its being turned round at will. The paring disc E is fixed on a spindle supported on the centres JJ, which allow of adjustment. By turning these tools round in the slightest degree when the working edge becomes blunt, an entirely new edge is presented to the work, and the whole of their circumferences is made available; they will work without being sharpened for 12 or 15 hours. When they require a new edge, they are placed on a spindle rotating at a high speed, and ground up by stone and oil slip in the ordinary manner.

The headstock of the rounding machine makes about 1200 revolutions per minute, and the yield of rounded stuff is from 2000 to 3000 feet run in a day of 10 hours. This machine has up to the present time been employed in the manufacture of broom and mop stails, umbrella sticks, &c.; each of the machines produces from 500 to 600 broom stails in 10 hours.

After leaving the rounding machine, the sticks are taken to the Heading Machine, which imparts a hemispherical form to one end. Figs. 6 and 7, Plate 112, show a side elevation and plan of the heading machine. It consists of a hollow spindle A, shown enlarged in Fig. 8, revolving in two bearings BB, driven by a pulley C in the ordinary manner. Extending from the end facing the operator is a semicircular guide D, grooved with adjustable V grooves, like those of an ordinary slide rest, but following the curve of the circle. In these grooves works a sliding quadrant E, to which is attached a box for holding the foot of the tool F; at the back of the sliding quadrant E is a rack, gearing into a pinion keyed on to a small spindle G, also hollow, which is fitted into the main spindle A of the machine. At the other end of the inner spindle G is placed the friction wheel H, by tightening which the sliding quadrant E is caused to follow the curve of the semicircular guide D towards the centre, or outwards, as desired. By the action of springs the cutter F has a tendency to remain as far from the centre of the spindle as possible, or at the extremity of the guide D. When an amount of friction is applied to the friction wheel H sufficient to overcome the elasticity of the springs, the tool F gradually moves towards the centre, describing a quarter of a circle in the guide D, whilst the whole is rapidly revolving.

The wood to be headed is held in a wooden clip I, which keeps it perfectly steady. A small maundril J with its front end pointed passes through the inner spindle G; this is advanced at pleasure by the wheel K acting on a screw, and the front point is placed a little behind the line of motion to be described by the tool. The tool F is then fixed at the proper radius from the centre line of the spindle, and the wood to be headed is pushed through the die or clip I against the advanced point of the maundril J, which assists in its support. As soon as the friction lever is applied to the wheel H, the tool F moves gradually along the guide D towards the centre, and completes the heading.

The machine is made to take in any rounded section of wood up to $2\frac{1}{2}$ inches diameter; a boy can head with ease 3 or 4 sticks per minute.

An Octagoning Machine, for giving an octagonal tapered form to pieces of wood of various sizes, is shown in Figs. 9 and 10, Plate 113. Four of the pieces of wood AA, sawn as nearly the required size and shape as is convenient, are fixed on a sliding plate B, between a set of steel centres CC at one end, and forks fixed in spindles DD at the other, the spindles being geared together so that all can be turned simultaneously by a lever. Four long cutters, of the section shown enlarged in Fig. 11, are fixed on a horizontal transverse shaft E, and caused to revolve with rapidity transversely across the four pieces of wood, thus taking off the corners of the square, as the plate B is advanced by the screw F placed underneath. The plate B is supported on two pins in a line with the centres of the pieces of wood, working in grooves G in the frame; this keeps the smaller end of the tapered wood of a uniform size, while by raising or depressing the other end of the plate B, by the interposition of different thicknesses of wrought iron to act as ways on which the tail end of the plate may work, the size of the larger end is altered as required. If the ways are irregular or varied in their form, the same variation in form will be imparted to the pieces of wood in the machine. As soon as one face is cut, by causing the spindles to make an eighth of a revolution, another surface is exposed to the cutters. This machine will octagon at the rate of 3 pieces of wood per minute.

A Conical Rounding Machine, for forming conical pieces of wood, such as handles of painters' brushes, oak trenails for railways, &c., is shown in Figs. 12 and 13, Plate 113. It consists of an upright revolving shaft H supplied with a driving fork, fitted into a hollow spindle I, with a feather to allow of its being raised or lowered at pleasure by the lever K. Lower down but in the same centre line with the shaft H is a maundril L, turned to the same shape as the required piece of wood. The head of the maundril L is made to fit a cast iron cylinder M, on the top of which is fixed the face plate N, carrying slides O fitted with cylindrical or other gouges according to the nature of the work. The gouges are advanced by levers P, the lower extremities of which press upon the maundril L;

and the face plate is raised or lowered by means of the small rack and pinion R.

The action of the machine is as follows:—the face plate N being lowered, the small end of the wooden cone S is placed in a cup at the head of the maundril L, and the other fixed on the revolving fork H. The maundril is then turned partly round, which allows the ends of the direction levers P to slip into grooves formed longitudinally in the maundril, and causes the tools to open or fly apart. The face plate is then raised as high as the top of the wooden cone, and the maundril is turned so as to place the extremities of the levers on its conical surface; and as the face plate is again lowered, the tools are drawn nearer together and turn the piece of wood to the desired shape. The revolving spindle H is then raised to release the work, and the process is repeated with another piece of wood.

The machines above described have been designed with the object of turning out a large quantity of work with great economy and despatch, by the use of tools that will work through the entire day, without the delay and expense arising from having them constantly sharpened, and requiring the attendance of a mere boy to supply the material and shift the cutters from time to time, so as to bring a fresh portion of the cutting edge into action. The cylindrical gouges and disc paring tools used in the rounding machine are proved by experiment to be applicable to the surfacing or planing as well as the rounding of timber; and it is not unlikely that their use might be advantageous in the working of other materials.

Mr. Wilson showed specimens of the cutters and gouges, and pieces of wood turned and shaped by the machines.

The Chairman enquired how long the new machines had been at work, and how many sets of machinery had been constructed on that plan.

Mr. Wilson replied that there was only one rounding machine at work at present, but two more were being made and would be at work shortly. The machine had been in constant work for about 9 months, during which time about 60 or 70 miles of broom handles had been turned out. It was intended to be applied also to other purposes, such as making cornice poles and other poles.

Mr. Waller asked what was the cost of one of the machines complete.

Mr. Wilson said the cost would be about £145 for the two machines for rounding and heading.

Mr. Wren Hoskyns enquired whether the economy of manufacture by the machine had been ascertained, as compared with the ordinary process.

Mr. Wilson replied that in the ordinary process of manufacturing broom handles the wood was planed by hand with a round semicircular plane, and a workman generally completed about 50 or 60 per day; but a boy with 3 machines could turn out 1500 per day.

Mr. H. Wright remarked that he had seen sledge and hammer handles made at Derby complete by machinery, in which the shaping of the wood was complicated by the varied forms required; he believed about 10,000 of these handles were made per week.

Mr. Wm. Smith, of London, stated that at the Royal Arsenal at Woolwich some American machines nearly similar in principle were employed in shaping wood in a very ingenious manner, making variations in the pattern within the length of the piece of wood operated upon.

Mr. Wilson said the general principles of the machine had been long and extensively in use; he had had the superintendence of similar machinery for making the hand railing or balustrade of the galleries in the Great Exhibition, which was produced in large quantities; similar machines were also in constant use at Keswick for making pencils. The only new invention in the present machine was in the form of the cutters, which were made with a circular edge so as to wear all round in succession; this was however a great improvement in practice, as the delay and expense attending the sharpening of the tools in previous machines were a serious drawback.

The die or hole in the face plate might be easily changed to suit different sizes of wood. The circular cutters were applicable also to surfacing stone, for which they might be extensively used with advantage, obviating the rapid wear of ordinary stone cutting tools.

The CHAIRMAN observed that he had seen in America a machine for planing stone, having a disc cutter fixed on three radial arms rotating slowly, which planed the stone very well; the cutter acted partly by cutting and partly by chipping the stone.

Mr. WM. SMITH said he had been informed that two of those stone cutting machines had been recently constructed by Mr. Cochrane, and he believed they were working efficiently in or near London.

The CHAIRMAN proposed a vote of thanks to Mr. Wilson for his paper, which was passed.

The CHAIRMAN announced that the next meeting of the Institution would be a Special Meeting in Manchester in the latter part of June, for which a Local Committee were actively engaged in making preparations, and an interesting and important meeting was expected.

The meeting then terminated; and after the meeting a couple of specimens were exhibited of a newly invented Pneumatic Signal Bell, by Mr. W. P. Maddison, of Barnsley. The bell is rung by a piston working loosely in a small cylinder, from which a small gutta percha tube leads off to any required distance; at the end of the tube is a small hollow india rubber ball, by a slight compression of which by hand the air is driven along the tube, forces the piston up in the cylinder, and causes it to strike the bell; distinct signals of two or three strokes can be readily given. This signal is being employed at the present time at the Lundhill Colliery, for the purpose of communication from the men employed at the shaft to the engineman; and also in workshops and offices.

Fig. 1. *Horse Windlass ready for work.*

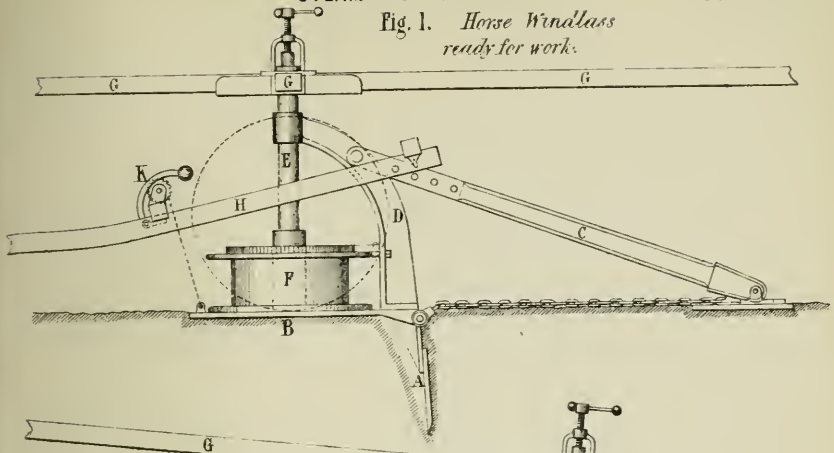


Fig. 2. *Horse Windlass ready for moving.*

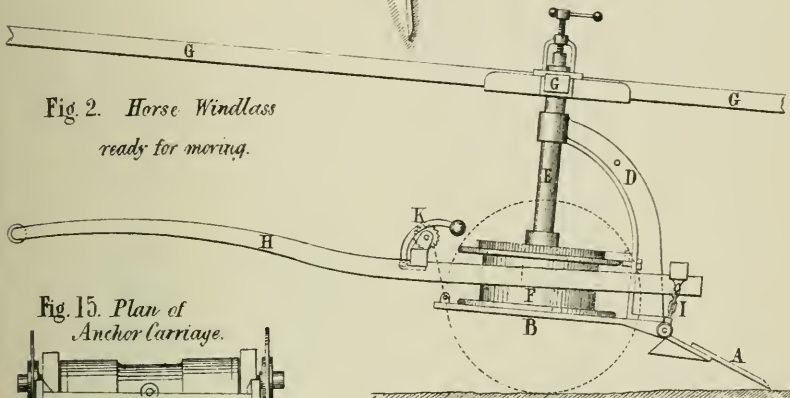


Fig. 15. *Plan of Anchor Carriage.*

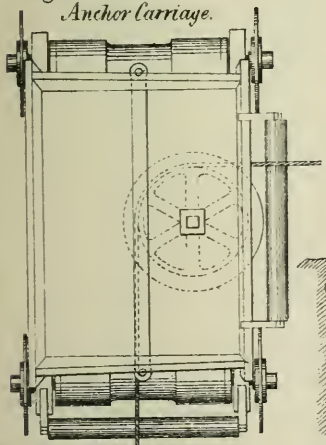


Fig. 7. *Back Elevation.*

Fig. 8. *Section.*

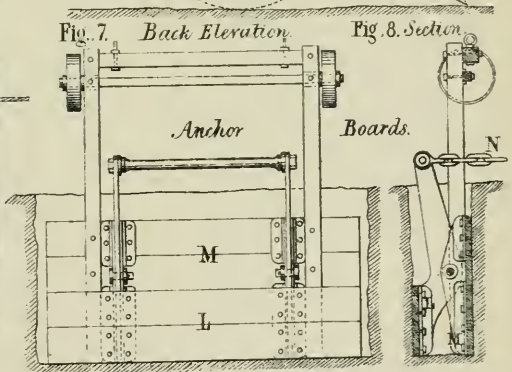
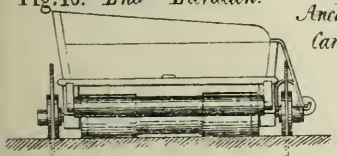
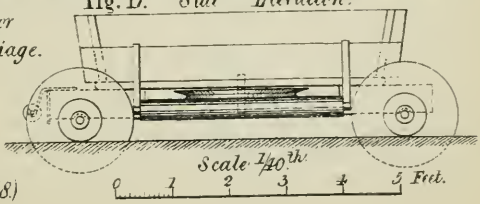


Fig. 16. *End Elevation.*



Anchor Carriage.

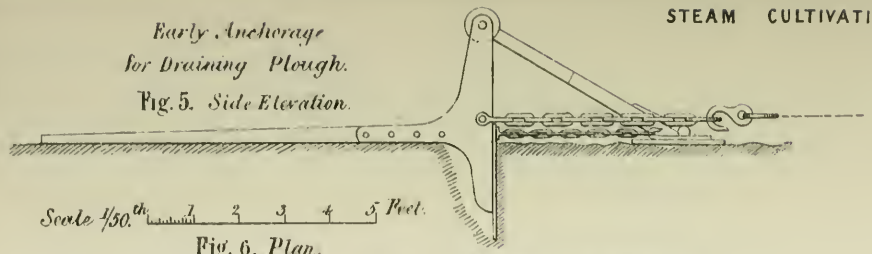
Fig. 17. *Side Elevation.*



(Proceedings Inst. M.E. 1857. Page 58.)

Early Anchorage for Draining Plough.

Fig. 5. *Side Elevation.*

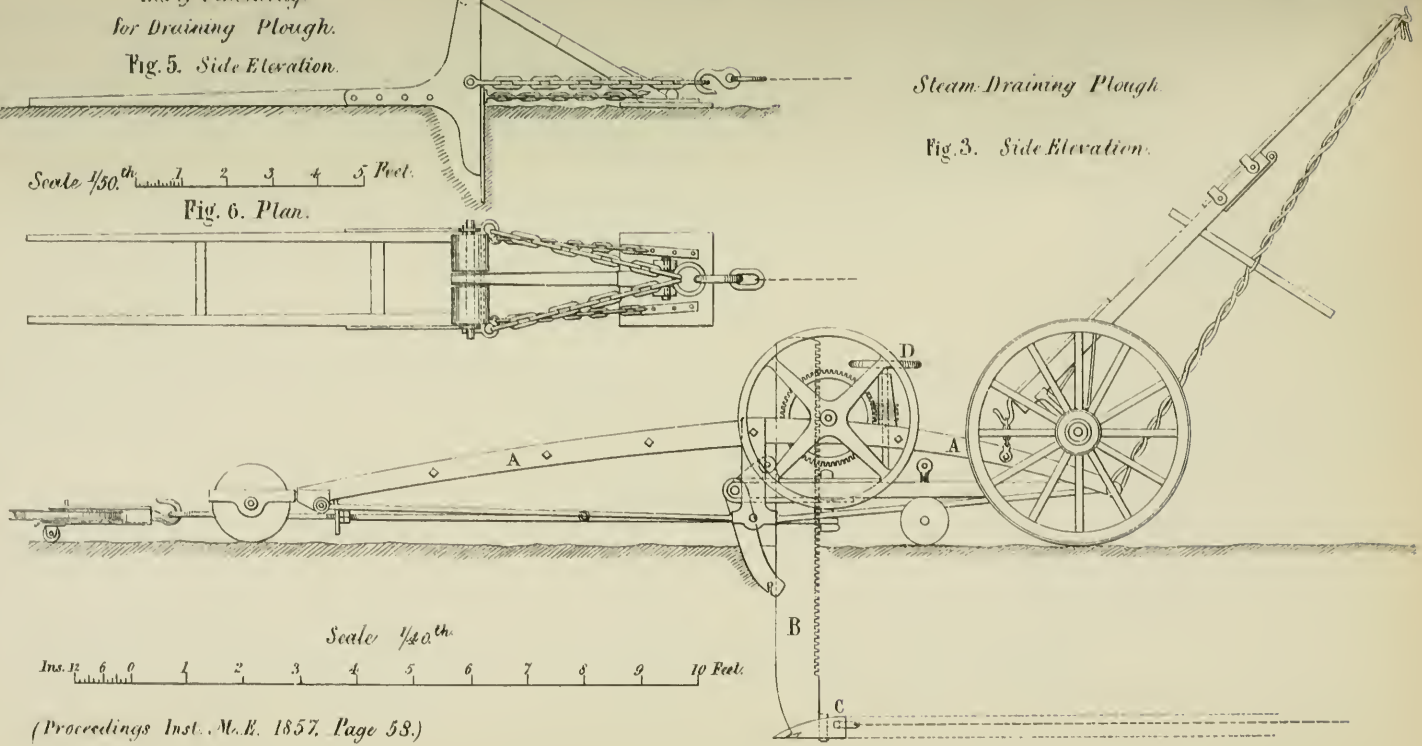


Scale 1/50th 1 2 3 4 5 Feet.

Fig. 6. *Plan.*

Steam Draining Plough.

Fig. 3. *Side Elevation.*



Scale 1/40th

Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet.

(*Proceedings Inst. M. E. 1857. Page 58.*)

Steam Cultivating Plough.

Fig. 11. *Side Elevation.*

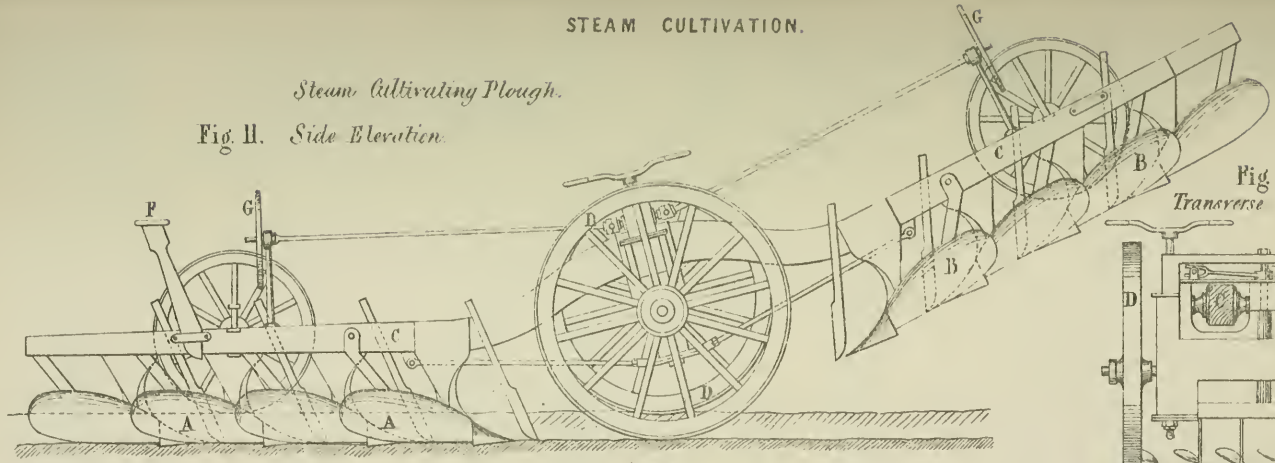


Fig 13.
Transverse Section.

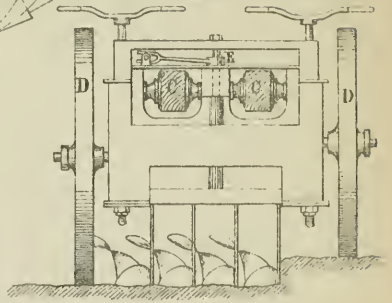
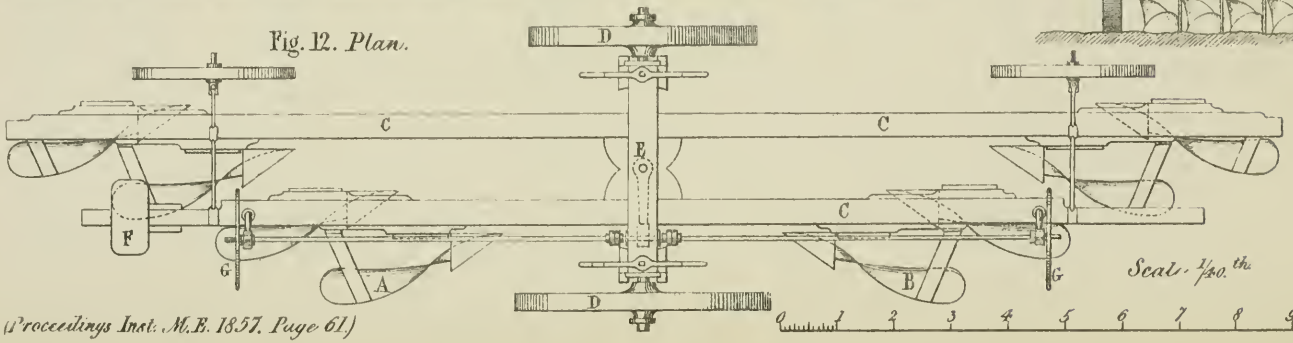


Fig. 12. *Plan.*



Scale 1/40th

0 1 2 3 4 5 6 7 8 9 10 Feet.

(Proceedings Inst. M.E. 1857. Page 61.)

Arrangements of Tackle for Steam Draining Plough

Fig. 4. Early Plan.

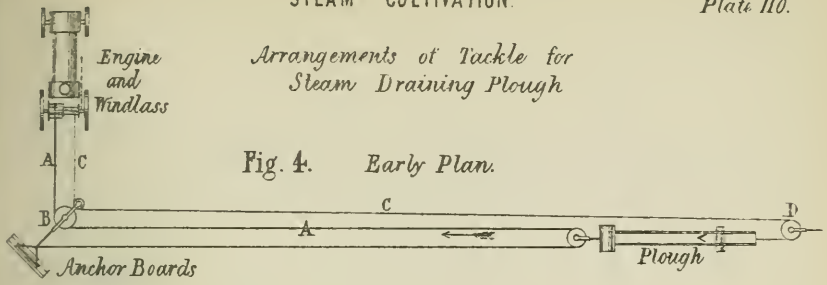
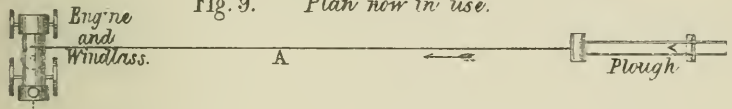


Fig. 9. Plan now in use.



Arrangements of Tackle for Steam Cultivating Plough.

Fig. 10. First Plan.

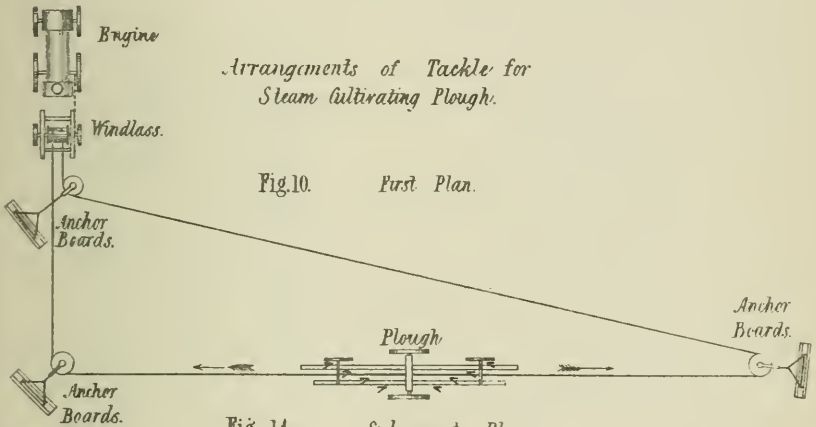


Fig. 14. Subsequent Plan.

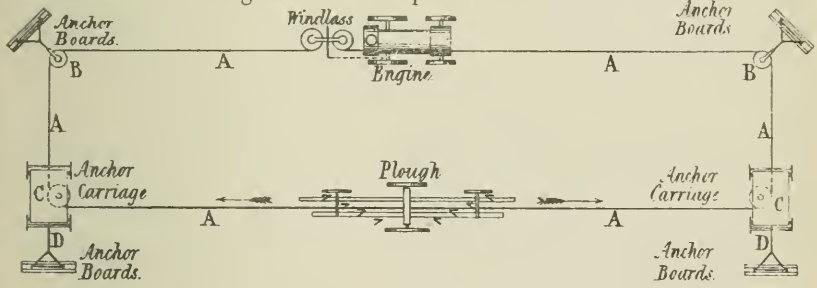
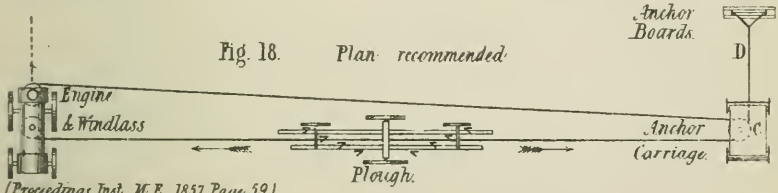


Fig. 18. Plan recommended.



(Proceedings Inst. M.E. 1857 Page 59)

Rounding Machine.

Fig. 1. *Side Elevation (part Section)*

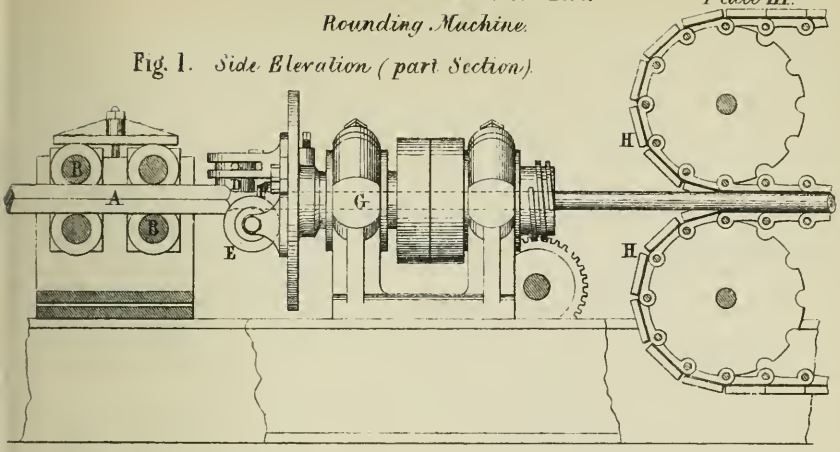


Fig. 2. *End Elevation.*

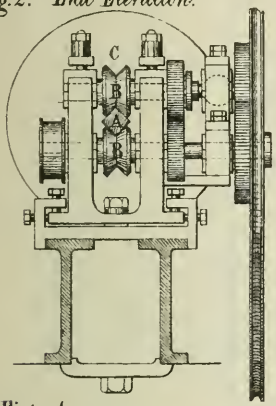
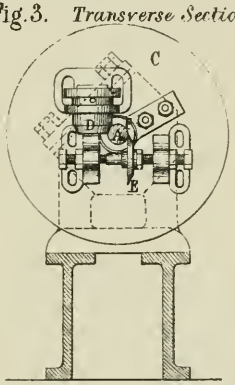


Fig. 3. *Transverse Section.*



Scale 1/12.th.

0 5 10 20 *Inches.*

Fig. 4.
Side Elevation of Face Plate.

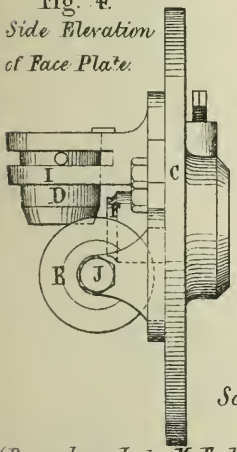
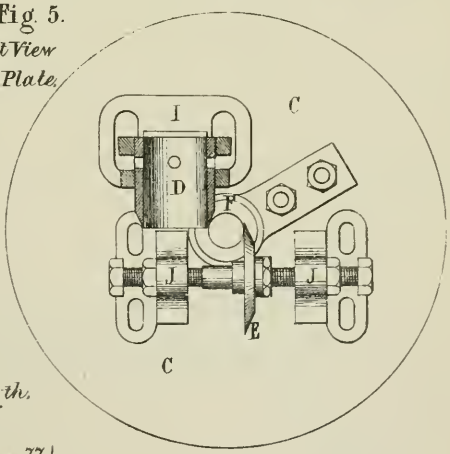


Fig. 5.
Front View of Face Plate.



Scale 1/6.th.

(*Proceedings Inst. M. E. 1857. Page 77.*)

Heading Machine.

Fig. 6. *Side Elevation.*

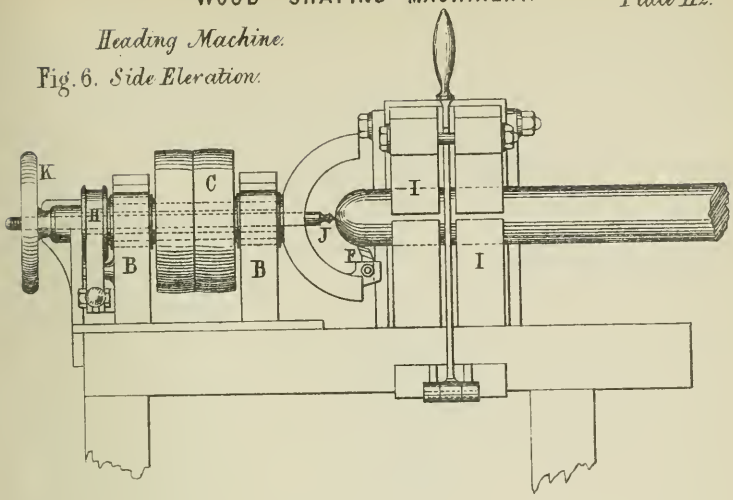


Fig. 7. *Plan.*

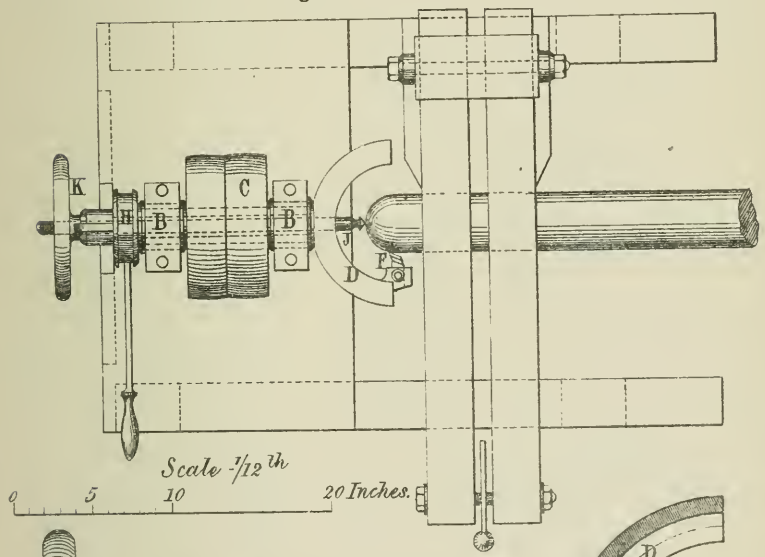
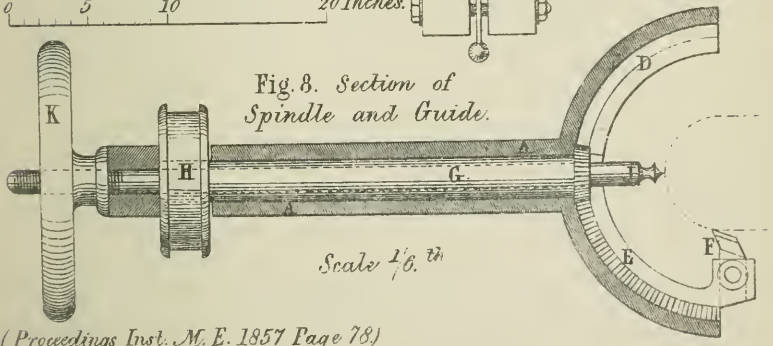


Fig. 8. *Section of Spindle and Guide.*



(Proceedings Inst. M. E. 1857 Page 78)

Octagoning Machine.

Fig. 9. Vertical Section.

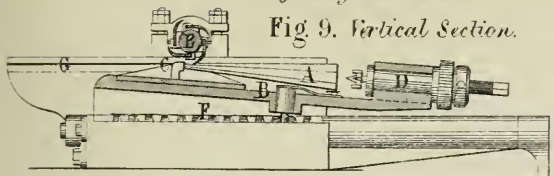


Fig. 10. Plan.

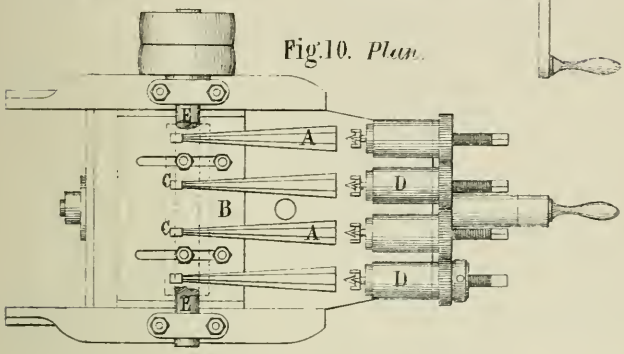


Fig. 11. Section of Gutter

Plan

Scale 1/6th.

Conical Rounding Machine.

Fig. 12. Side Elevation.

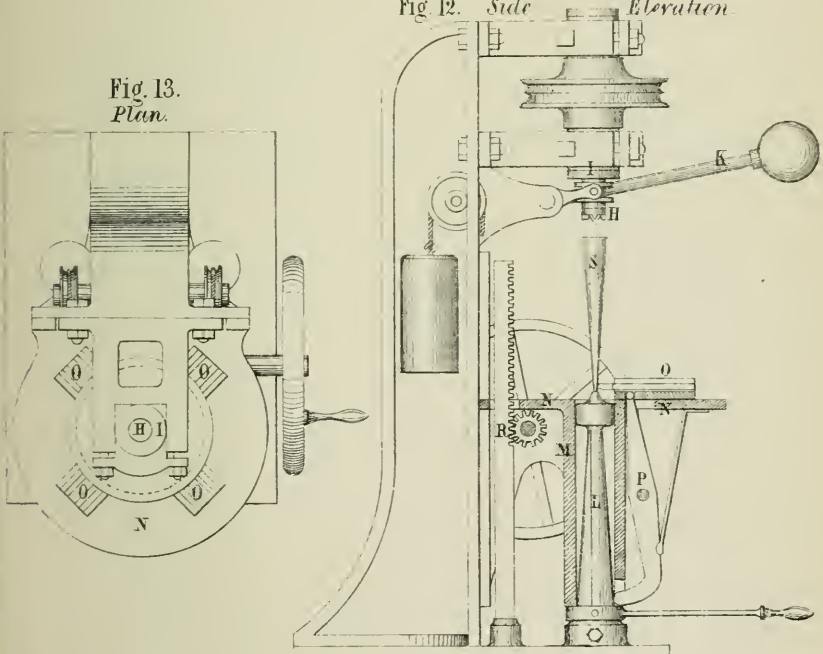


Fig. 13. Plan.

Scale 1/12th. 0 5 10 20 Inches.

(Proceedings Inst. M. E. 1857. Page 79)

PROCEEDINGS.

24 and 25 June, 1857.

The Special General Meeting of the Members was held in the Rooms of the Mechanics' Institution, David Street, Manchester, on Wednesday, June 24th, 1857; Joseph Whitworth, Esq., President, in the Chair.

The Secretary read the Minutes of the last General Meeting, which were confirmed.

The Chairman announced that the inauguration of the Statue of James Watt, which had just been erected in front of the Infirmary in Manchester, was to take place on Friday next at noon, and the attendance of the Members of the Institution was invited on that occasion, as a tribute of respect to the memory of that great Mechanical Engineer.

Mr. Fairbairn, as Chairman of the Committee for the erection of the Monument, said that the Committee had deferred the inauguration to the Meeting of the Institution in Manchester. The Committee conceived it an appropriate opportunity for doing honour to the name of Watt, and he was sure it would be equally gratifying to the Members to be present on the occasion. The monument was a bronze statue of James Watt, modelled from the original by Chantrey, and erected by private subscription as a companion to that of John Dalton, already placed on the same spot.

Mr. McConnell proposed a vote of thanks to the Chairman and the Committee, and expressed the great gratification he felt at the opportunity being so kindly afforded for the Members to be present on that interesting occasion. He thought it very honourable to Manchester that they had raised so suitable a monument to that great mechanic, to whom all manufactures and the whole civilised world were so remarkably indebted.

Mr. Henry Maudslay seconded the motion, which was passed; he expressed the great pleasure he felt at the invitation, and his sense of the marked compliment to the Institution, which he was sure would be fully appreciated by the Members.

Mr. Fairbairn acknowledged the vote of thanks, and said the Committee were glad to have had the opportunity of arranging the inauguration for an occasion so highly important as that of the meeting of the Institution of Mechanical Engineers in a district so deeply indebted to the inventions and discoveries of Watt.

The following Paper, by Mr. William Fairbairn, of Manchester, was then read :—

ON TUBULAR WROUGHT-IRON CRANES; WITH DESCRIPTION OF THE 60 TON TUBULAR WROUGHT-IRON CRANE RECENTLY ERECTED AT KEYHAM DOCKYARD, DEVONPORT.

About seven years ago the first design for a Wrought-Iron Crane was submitted to the Admiralty for their approval. It was a crane calculated to afford greater security and facility in the removal or shipment of stores on board vessels, and in other respects better qualified for raising heavy weights than those hitherto in use. The design was placed in the hands of the Surveyor of the Navy, and Mr. Lloyd, Inspector of Machinery, who were so well satisfied as to the superiority of the construction that an order was given to erect six of them in different positions along the line of quays of the new Keyham Docks at Devonport.

These cranes were all of the same size and strength, and were calculated to lift a weight of 12 tons to a height of 30 feet from the ground. Each of them was intended to sweep a circle of 65 feet diameter, so that the projection of the jib was 32 feet 6 inches from the centre of the stem, and the extreme height 30 feet above the working platform. The cranes are composed of wrought iron plates rivetted together, and so arranged as to give the back or convex side an adequate degree of strength to resist tension, and the front or concave side, which is of the cellular construction, a corresponding power to resist compression. The form is similar to that of the prolonged vertebræ of the bird from which the machine takes its name; it is truly the neck of the crane, tapering from the point of the jib, where it is 2 feet deep by 18 inches wide, to the level of the ground, where it is 5 feet deep and 3 feet 6 inches wide. From this point it again tapers to a depth of 18 feet below the surface, where it terminates in a cast iron shoe forming the toe on which the crane revolves. The lower or concave side, which has to resist a force of compression, consists of plates forming three cells and varying in width in the ratio of the strain; and on the other hand, the convex or top side, which has to bear the pull or tension due to the suspended weight, is formed of long plates connected together by the system of "chain rivetting," first applied in the great tubular bridges in Wales.

The sides are of uniform thickness throughout, the joints being covered with T iron internally, and on the outside with strips or covering plates $4\frac{1}{2}$ inches wide.

The form of the jib, shown approximately in Fig. 8, Plate 117, together with the point at which the load is suspended, is probably not the most favourable for resisting pressure. The crane nevertheless exhibits great powers of resistance, and may safely be considered as a curved hollow beam having one end immoveably fixed, the force being applied at the other. Viewing it in this light the strength is easily determined from the formula

$$w = c \frac{a\ d}{l}$$

where w is the breaking weight at the end of the jib in tons; c the ultimate resistance of wrought iron to compression in tons per square inch; a the sectional area of the lower or cellular flange in square inches; d the depth in inches; and l the horizontal length or sweep of the jib in inches: the strength being supposed to be limited by the resistance of the lower or cellular flange to compression. From this formula it is found that it would require a load of 63 tons to break one of these cranes.

As this was an entirely new construction, it was considered desirable to test its powers of resistance to strain, and to determine by direct experiment the law of strength which it followed. To accomplish this, each of the cranes was loaded progressively with weights up to 20 tons, the deflections being carefully recorded as the experiment proceeded.

The following Table I. gives the results of the experimental tests to which the Keyham and Devonport cranes have been subjected.

No. 1 Crane.—8 Nov. 1850. With 5 tons suspended the crane was turned completely round without any alteration in the deflection. With 10 tons suspended the crane was again turned round, and in 8 minutes the deflection increased from 1·70 inch to 1·85 inch, at which it remained after sustaining the load during the whole of the night, a period of about 16 hours. The next day the experiments were resumed; and on turning the crane round with a load of 20 tons, there was no perceptible alteration in the deflection, and the permanent set after removing the load was ·64 inch. Hence the deflection was 3·33 inches for a load of 20 tons. The ultimate strength of the crane is therefore much greater than is requisite in

TABLE I.

Deflection of Tubular Wrought-Iron Cranes.

Load at end of Jib.	Deflection at end of Jib.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Tons.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	·32	·31	·37	·25	·27	·31
3	·50	·50				
4	·65	·62				
5	·90	·87	·87	·75	·88	·82
.. turned round	·90	·87	·87	·75	·88	·89
6	1·05	1·06				
7	1·20	1·18				
8	1·35	1·37				
9	1·50	1·50				
10	1·70	1·68	1·70	1·62	1·62	1·76
.. turned round	1·85	1·87	1·80	1·62	1·62	1·76
11	2·05	2·05				
12	2·22	2·19				
13	2·40	2·40				
14	2·60	2·62				
15	2·80	2·80	2·69	2·56	2·63	2·31
.. turned round	2·80	2·86	2·69	2·56	2·68	2·31
16	3·00	3·00				
17	3·20	3·31				
18	3·50	3·50				
19	3·73	3·69				
20	3·97	3·92	3·56	3·56	3·62	3·75
.. turned round	3·97	3·92	3·56	3·56	3·62	3·75

either theory or practice; and although tested with nearly double its intended load, this was still far short of its ultimate power of resistance, which by calculation is five times greater than its nominal power.

No. 2 Crane.—8 Oct. 1851. With 5 tons suspended the crane was turned completely round without any perceptible change in the deflection. With 10 tons suspended the crane was again turned round, when the deflection increased from 1·68 inch to 1·87 inch; on removing the load the permanent set was found to be ·25 inch, being the amount of loss of elasticity due to a load of 10 tons suspended from the extreme point of the jib. With 15 tons suspended the crane was turned round with an increase in the deflection of only ·06 inch. Previous to removing the final weight of 20 tons the crane was turned round, in order to test the efficiency of the moveable

parts, and also the break wheel, which at this trial was used for lowering the load. On removing the weights, it was ascertained that the retaining powers of the rivetted joints and the elasticity of the parts in combination exhibited rather more tenacity than in the first crane that was made, as the jib when relieved from the load of 20 tons rose to within ·62 inch of its original position.

No. 3 Crane.—7 Jan. 1852. In this and the succeeding experiments the cranes exhibit still greater powers of resistance as regards the strength or ultimate deflection of the jib. The defects of elasticity are also diminished to an extent which clearly shows that the workmen had become more expert and probably more careful in the fitting and rivetting of the parts.

In turning round the crane No. 3, the deflection remained unaltered with 5 and 15 tons load, but increased ·10 inch with 10 tons load. On removing the load of 20 tons the permanent set was found to be only ·40 inch, which gives 3·16 inches as the deflection due to the load of 20 tons.

No. 4 Crane.—4 Feb. 1852. The results of the experiments on this crane correspond closely with those enumerated for No. 3. The same indications of strength, elasticity, and deflection follow each other with remarkable precision. No alteration in deflection took place when the crane was turned round with loads of 5, 10, and 15 tons. The crane was turned round with the load of 20 tons, when the permanent set was found to be ·62 inch, making the deflection 2·94 inches for the load of 20 tons.

No. 5 Crane.—6 Feb. 1852. This crane was subjected to the same treatment with nearly the same results. In turning it round with 5, 10, and 20 tons load the deflection remained the same ; with 15 tons load the deflection increased ·05 inch in turning round. On removing the load of 20 tons, the permanent set was ·44 inch, giving a deflection of 3·18 inches due to the load of 20 tons.

No. 6 Crane.—14 Feb. 1852. In turning round with 5 tons load the deflection increased ·07 inch ; but with 10, 15, and 20 tons load no change took place in turning round. On removing the load of 20 tons, the permanent set was ·50 inch, giving a deflection of 3·25 inches for the load of 20 tons.

In the above experimental tests, it is satisfactory to observe, that the resisting powers of this construction are limited only by the weight of the foundations and the strength of the chains, wheels, and machinery for lifting the load. For a crane of 12 tons has a stem and jib capable of supporting 60 tons, or five times the load it

is intended to bear, a much greater margin than is generally allowed for constructions of this kind.

The following Table II. gives a summary of the results of the experiments, showing the deflection and permanent set in each crane with the final load of 20 tons.

TABLE II.

Summary of Results.

Number of Crane.	Deflection at point of Jib with 20 tons load.	Permanent Set with 20 tons load.
	Inches.	Inch.
No. 1	3·97	·64
No. 2	3·92	·62
No. 3	3·56	·40
No. 4	3·56	·62
No. 5	3·62	·44
No. 6	3·75	·50
Average	3·73	·54

The average permanent set being deducted from the average final deflection leaves 3·19 inches as the average deflection for a load of 20 tons, which is at the rate of ·16 inch per ton. These experiments present a remarkable consistency and uniformity in the strength and elasticity of the material under strain; and it will be observed that the permanent set, varying from ·40 inch to ·64 inch, is small in amount, when compared with the load and the peculiar nature of the strain to which the jib was subjected.

In the construction of cranes, whether of wood or iron, it has been the usual custom to place the jib in an inclined position at an angle of about 40° or 45° with the stem, as in Figs. 6 and 7, Plate 117, so as to obtain the greatest strength; in this position the extreme point from which the load is suspended has to be stayed or held in its place by oblique or horizontal tie rods. With this arrangement it will be observed that, if the article to be raised be at all bulky, such as a large bale of merchandise or a marine boiler, it will be prevented from being elevated to the top of the crane by coming in contact with the diagonal stay or jib. Hence with ordinary cranes a considerable part of the height is practically unavailable. In the wrought-iron crane however, Fig. 8, this defect

is obviated, since the curvature of the jib is sufficient to allow the article to be raised to the highest point to which the chain ascends.

The advantages peculiar to this construction of crane are its great security and the facility with which bulky and heavy bodies can be raised to the very top of the jib, without the least risk of failure. It moreover exhibits, when heavily loaded, the same restorative principle of elasticity as is so strikingly exemplified in the wrought iron tubular girders. These constructions, although different in form, are nevertheless the same in principle, and undoubtedly follow the same law as regards elasticity and power to resist fracture.

Several cranes of the same power and construction have lately been erected at Keyham, Devonport, Birkenhead, and Southampton, and at St. Petersburgh, all of which have been severely tested by the suspension of weights considerably greater than they were intended to bear. Ten ton and three ton cranes have been experimented upon in a similar manner and attended with the same results; all of them exhibiting great powers of resistance, greatly increased convenience for raising the load under the curvature of the jib, and equal facility in moving the crane to any point within reach of the sweep.

Subsequently to the erection of these, the first cranes on the tubular principle, a number of others followed of different dimensions and for various purposes, all of which exhibited the same powers of resistance and other advantages. It is however due to the Government to state that they took the initiative in the introduction of this new system, and finding the first six cranes answer the purpose they ordered two more for Devonport and a 60 ton crane of colossal dimensions for Keyham. This latter construction is the one selected for particular description in the present paper.

The large 60 ton tubular wrought iron crane, recently erected at Keyham Dockyard, is shown in Figs. 1 to 5, Plates 114 to 116.

Fig. 1, Plate 114, is a sectional elevation of the crane, showing the general arrangement, and the well in which the crane is placed; and Fig. 2 is a corresponding plan.

Fig. 3, Plate 115, is an enlarged vertical section of the lower portion of the crane.

Figs. 4 and 5, Plate 116, are sectional plans of the crane at the level of the ground, and at the chain barrel and gearing.

The crane consists of a rectangular wrought iron tube AA, Fig. 1, curved to a radius of about 46 feet, and tapering uniformly from 9

feet deep by 5 feet 6 inches wide at the level of the ground, where from the leverage of the crane the strain is the greatest, to 3 feet 6 inches deep by 2 feet wide at the point of the jib. From the level of the platform it is also tapered downwards to about 1 foot 8 inches square at 23 feet below the level of the ground, where it fits into a cast iron shoe B working in a socket or step on which the crane revolves. The point of the jib is 60 feet above the level of the platform and sweeps a circle of 53 feet radius; so that it will lift the heaviest load perpendicularly from a mean distance of 37 feet from the quay wall, and to a height of no less than 85 feet above low water mark, and land it at 69 feet from the edge of the quay.

The crane itself is built on precisely the same principle as a tubular bridge, and may indeed be considered as a curved tubular girder inverted, the top side being the front or concave side of the crane, and the bottom side forming the convex or back part of the structure. Hence it may be described as composed of back plates, side plates, and cell plates.

The back plates C, Figs. 3 and 4, which, corresponding with the bottom plates of a tubular girder, have to resist a strain of tension, are made as long as possible to avoid joints, and are carefully chain rivetted. They are $\frac{3}{8}$ inch thick and each half the width of the crane; and taking those on one side and beginning at the bottom of the well, the first back plate is 13 feet 9 inches long; the second, which passes the point where the downward taper ends and the upward begins, is 13 feet 6 inches long; the next is 12 feet 6 inches, followed by six others, each 12 feet long, and these again terminated by a plate 15 feet long which curves round over the pulley at the extreme point of the jib. These plates are covered externally by a long strip 8 inches broad and $\frac{3}{8}$ inch thick, extending the entire length of the crane and covering the longitudinal joint between the back plates. The cross joints are placed alternately, and at each side of the crane there is a line of angle iron connecting the back plates C with the side plates D, Figs. 3 and 4. So that the sectional area of the back of the crane subjected to tension is

At the bottom	... ...	10·50 square inches.
At the platform	... ...	27·75 „
At the point of the jib	...	12·00 „

The sides of the girder are formed of plates 3 feet broad at the outer edge or back of the crane, rivetted together with T iron 4 × 2 × $\frac{3}{8}$ inches at every joint inside, and a strip outside, to give the

necessary rigidity. Beginning at the toe, the first three plates are $\frac{3}{8}$ inch thick; the next three $\frac{5}{16}$ inch; the next five, which have to resist the horizontal thrust against the cast iron circle at the top edge of the well, $\frac{3}{8}$ inch thick; and the remainder $\frac{5}{16}$ inch thick.

The front of the crane is constructed with four cells, to resist the immense strain of compression to which that part is subjected. The construction is shown in the sectional elevations, Figs. 1 and 3, and the transverse sections, Figs. 4 and 5. The two series of plates E and F, which form the front and back of the cells, are composed of plates varying from 5 feet to 7 feet 6 inches long, and $\frac{5}{16}$ inch thick. Each of these plates is rivetted by two angle irons to the side plates D of the crane, the front plates E projecting beyond the side plates D, and the intermediate plates F being placed within the tube thus formed at a distance of 12 inches from the front plates E, so as to divide the tube into two. The narrow space between the plates E and F is further subdivided into four cells by three vertical plates G, parallel to the side plates D. Eight angle irons connect the plates G with the plates E and F, and further strengthen the structure thus formed. The reason of this arrangement is that wrought iron plates from their flexibility offer but a small resistance to compression in the direction of their thickness, as they bend or buckle with a comparatively small force. The five vertical plates however, which form the sides of the cells, are placed in the position in which they offer a maximum resistance to compression, namely with their width or depth in the direction of the strain; and the angle irons and the plates E and F serve to keep them in position and give great rigidity to the structure. The centre plate G of the cells is $\frac{5}{16}$ inch thick, and the two remaining plates each $\frac{4}{16}$ inch thick. The sectional area of the concave or front part of the crane subjected to compression is therefore

At the platform	62·58 square inches.
At the point of the jib ...	34·83 „

Attached to the back of the crane is a tail piece H or box of wrought iron, containing cast iron weights acting as a counterpoise to the jib. The chain I is attached to the crane by a bolt and nut at the point of the jib, and passes round four pulleys, two moveable and two fixed in the end of the jib; it is then conducted down in the interior of the jib over three rollers K to the barrel L which is also in the tube near the ground. On each side of the crane a strong cast iron frame is fixed for receiving the axles of the spur wheels and

pinions. Four men, each working a winch M of 18 inches radius, act by two 6 inch pinions upon a wheel N, 5 feet $3\frac{3}{4}$ inches diameter; this in its turn moves the spur wheel O, 6 feet 8 inches diameter, by means of an 8 inch pinion, and on the axle of the former the chain barrel L, 2 feet in diameter, is fixed. Hence the advantage gained by the gearing will be

$$\frac{W}{P} = \frac{18 \times 63{\cdot}75 \times 80}{6 \times 8 \times 12} = 158;$$

or taking the number of cogs in each wheel

$$\frac{W}{P} = \frac{18 \times 95 \times 100}{12 \times 9 \times 10} = 158;$$

and as this result is quadrupled by the fixed and moveable pulleys, the power of the men applied to the handles is multiplied 632 times by the gearing and blocks. A break wheel P, Fig. 5, 5 feet 2 inches diameter, is fixed on the other end of the spindle of the spur wheel N; and the power applied at its circumference is accordingly multiplied about 100 times by the gearing and blocks.

At the level of the ground the crane is firmly fixed in a strong cast iron frame R, Figs. 3 and 4, the outer edge of which is a circle of 11 feet 3 inches diameter; and on the edge of the well a similar ring S is embedded in the masonry and secured by long holding-down bolts, leaving a space of 10 inches all round between it and the inner ring R. In this space a number of strong cast iron rollers T are placed, 10 inches in diameter, to prevent friction and facilitate the movement of the crane as it revolves round its axis. Upon the cast iron ring S on the quay wall is fixed a circular rack U, composed of cogged segments bolted together, into the teeth of which a small pinion works, whereby the crane is made to revolve. This pinion is worked by a worm and wheel V placed in the counterpoise box H; and two men are sufficient to move round the crane with 60 tons suspended from the extreme point of the jib. In working the crane the men stand upon a cast iron platform W attached to it a few inches above the level of the ground.

This crane, taking it altogether in regard to its strength, height, and the extent to which the weight raised can be swung round, is probably one of the first and most powerful in Europe. It can raise or lower boilers in and out of the hold of ships of the line; pick up the heaviest ordnance from any of the decks; and ship or unship masts with the same or greater ease than is now done by the large

shears used for that purpose in any of the dockyards. In fact a colossal crane of this description, 120 feet high, was submitted to the surveyor of the navy as a substitute for the large masting shears at Woolwich, which were worn out; but owing to some other arrangement the project was not carried into effect.

Mr. Fairbairn observed that the principal features of the crane were the clear headway space at the very extremity of the jib for lifting bulky masses such as marine boilers, &c., to the full height of the crane, and the great ease of turning and management, notwithstanding its enormous size and strength. A large number of friction rollers, 10 inches diameter, were fitted into two iron rings travelling round the large centre post, which was enlarged to 11 feet diameter at that part, supporting the single wrought iron tubular structure forming the jib of the crane. Great ease of motion was experienced in turning the crane round even with the very heavy weights that were lifted by it. This construction was more particularly applicable for masting ships and raising ponderous loads to a great height, for which it was not more expensive than other constructions. It had great advantages in convenience and efficiency over most others; and for small cranes it was not more expensive than those now in use.

Mr. McConnell observed that in the experiments upon the deflections of the jib, that were described in the paper, the total amounts of deflection appeared to have preserved an almost uniform proportion to the load;—5 tons giving about 1 inch deflection, 10 tons 2 inches, 20 tons 4 inches;—so that the crane jib had deflected as regularly as if consisting of a single piece, which was a very satisfactory result, showing the efficiency of that mode of construction. He enquired whether any lines had been taken showing the alterations in the curve of the crane jib during deflection, in order to ascertain what comparative variation there was in the different portions. There would be a very severe strain of tension upon the middle of the convex side of the jib, tending to alter the curve of the jib when loaded.

Mr. Fairbairn replied that there had not been an opportunity for correctly noting the change in the curve of the jib; the deflections were recorded only at the extremity. In finally determining the proportions and curve for the jib, he had, on commencing the construction of the cranes, a model made in two portions divided transversely at the middle point of the length and connected by a hinge at the lower side; and then by means of a cord passing over the convex side of the crane the strain of tension was correctly measured by a weight. The jib was not correctly proportioned at first, and showed indications of giving way on reaching 60 tons load, the deflection being nearly 1 foot at the extremity; the most severe strain appeared to be on the back of the crane, where the plates gave way by tension owing to a defect in the joint at that part. He had to make good the injury, and finally obtained a due proportion of the strength in the different parts which appeared to afford a more equal distribution and to leave very little of the material in excess at any one point.

Professor Rankine enquired what was the strain per square inch in tension and compression upon the iron of the plates forming the jib, when the proof load was on the crane.

Mr. Fairbairn said that about 3 tons per square inch compression and 4 tons per square inch tension was the usual calculation he adopted for the strain under the proof load in wrought iron plate structures; but a larger margin of strength was allowed in these cranes as an extra precaution.

Mr. Hawkes remarked that from the dimensions given the strain appeared to be only about 2 tons per square inch with the proof load of 60 tons; which would leave an unusually large margin for safety, as the material was generally considered not to begin to stretch permanently under a strain of 9 tons per square inch.

Mr. Fairbairn said the ultimate resistance of wrought iron to tension was about 20 or 22 tons per square inch, but the exact limit of permanent stretching was uncertain; it was formerly supposed to be at about 1-3rd of the breaking strain, but it was now found that 1-10th of the breaking weight would produce ultimately a permanent set, though very small in amount, and perhaps even 1-20th would do so if left on for a considerable length of time.

Mr. Hawkes asked whether it was recommended that not more than 2 tons per square inch should be calculated as the proof strain in such cases as wrought iron cranes.

Mr. Fairbairn considered that was undoubtedly a very low limit; but in cranes of the unprecedented size of those now described, it was advisable to allow a considerably larger margin than usual in the calculation, from the serious consequences of any accident, and the severe jar and shock that would be caused if any surging of the chain took place in lifting such enormous weights. The whole structure must be looked upon as imperfectly elastic, and subjected to constant bending and springing in its working condition; and it was essential to the security of the structure to prevent any risk of the strain ever reaching an amount capable of producing permanent injury.

Professor Rankine supposed the question of permanent set was not now the important practical point, as it appeared that the permanent set decreased gradually instead of having any actual vanishing point; but the question of importance was where appreciable permanent injury really began.

Mr. Fairbairn observed that 60 tons load was the limit intended to be put upon the largest crane described; but he would not fear to try it with 200 tons, and thought it would be quite safe at that load.

The Chairman proposed a vote of thanks to Mr. Fairbairn for his paper, which was passed.

The following Paper, by Mr. James Fenton, of Low Moor, was then read:—

ON A NEW WATER CONNEXION BETWEEN LOCOMOTIVE ENGINES AND TENDERS.

Since the first introduction of the locomotive engine, now more than a quarter of a century ago, several plans have been adopted for connecting the feed pipes of the engine and tender, capable of resisting for a time without leakage the great wear that takes place in the ordinary course of running, which is accelerated by blowing steam from the boiler of the engine into the tender tank. All these plans however have been expensive either in first cost, or to keep in repair, or both. Those most generally in use are the ball and socket pipes, and the flexible tubes or hose pipes. Other and more recent inventions have been tried, but the author believes they have not been attended with an amount of success sufficient to ensure their general adoption. The ball and socket connexions prove a continual source of annoyance and expense to all who have them in use on their locomotive stock; and the flexible tubes or hose pipes are scarcely less troublesome.

With the view of remedying this acknowledged defect in one of the details of the locomotive engine, the author's attention was directed to the subject, and the water connexion described in the present paper is the result.

Fig. 1, Plate 117, is a longitudinal section of the water connexion, and Fig. 2 a transverse section. Fig. 3 is a full size section showing the rolling packing ring.

AA are two cylinders of brass or iron, one of which is bolted in the usual manner to the feed pipe of the engine, and the other to that of the tender; they are both bored out smooth and parallel. BB is a connecting tube of brass or iron, having the ends turned, the part from C to D, Fig. 3, being parallel, and that from D to E coned; the collars F are curved as shown in the figure. GG are elastic rings of vulcanised india rubber, which when at work roll between the cylinders AA and the connecting tube B. II are light chains used for the purpose of keeping the tube B in its proper position; they are each left slack to an extent of one half the greatest amount of travel required between the engine and tender.

The advantages which this arrangement appears to possess are its extreme simplicity, and consequent cheapness both in first cost and current repair; and the great durability of the only wearing parts, the motion of the elastic rings when at work being a *rolling* instead of a *rubbing* action. Also the absolute tightness of the joints when steam is blown from the boiler into the tender tank, as the elastic rings GG are then forced up the cones DE by the increased pressure, and are only prevented from being blown out by the collars F, which are curved as shown in Fig. 3, for the purpose of enabling the rings again readily to adjust themselves to their proper position when the pressure is removed, which they do as soon as the engine is put in motion.

The india rubber rings G are made slightly larger than the space into which they fit, for the purpose of ensuring a thoroughly water tight joint; the cylinders A are $3\frac{1}{16}$ inches inside diameter, and the tube B 2 inches outside diameter, as in the figure; the ring is made $3\frac{1}{8}$ inches outside diameter, and $1\frac{7}{8}$ inch inside diameter, the section of the ring being a circle $\frac{5}{8}$ inch diameter.

Should either of the tender valves get out of order on the journey, and it becomes necessary to stop the feed by other means, it is only requisite to slack back the bolts which hold the flanges K together, and introduce a piece of sheet iron or zinc between them, of sufficient width to cover the orifice of the feed pipe. This simple and effectual mode of stopping the feed was suggested and adopted by Mr. Ramsbottom, of the London and North Western Railway, on which, as well as on several other lines of railway, this water connexion has been in successful operation for several months.

Mr. Fenton showed a specimen of the new coupling pipe, partly cut open in order to show the action of the india rubber rings; also separate specimens of the rings.

Mr. Ramsbottom said he had had one of these coupling pipes in use rather more than 2 months on a locomotive, and it had worked so far very satisfactorily; the india rubber rings showed no signs of wearing out at present. He thought it decidedly a good plan, and likely to prove advantageous in use.

Mr. Craig had had one of them at work about 3 months, applied to a stationary force pump working under 300 lbs. per inch pressure, and it had proved quite successful. He had now applied them to several locomotives, and was well satisfied with the results; he considered they would require much less expense to keep in order than either the hose pipes or the ball and socket couplings ordinarily employed, and the economy of first cost was also in their favour.

Mr. T. Forsyth thought there was no doubt of the success of the plan with cold water, as shown by long experience of the successful working of the same rolling india rubber packing in Kennedy's water meter; but he understood that when fixed near to a boiler for measuring the feed water, the india rubber ring was found to be injuriously affected by the heat; and he feared that when used much with steam blown through into the tender, the rings would not be found to stand.

Mr. Fenton said he expected they would prove quite satisfactory in that respect, as some of the couplings had already been working 3 months with the original rings, in regular work exposed to the ordinary blowing through of steam into the tender, and the rings were still at work showing no sign of injury. But even if they were frequently worn out the whole cost of maintenance would be very small, as it cost only 6*d.* each to renew the rings, or 2*s.* per set; so that even a set per month might be used, and leave the cost of repairs much below that of any other couplings; all the rest of the apparatus suffered no deterioration from years of work, but the canvas and india rubber hose pipes had to be entirely renewed when worn out, and the brass couplings frequently required expensive repairs in consequence of grit getting into the slides and cups and wearing the rubbing surfaces.

Mr. Craig had found some india rubber hose pipes last as long as 8 or 9 months exposed to 120 lbs. steam; but their ordinary duration was only about 6 months, when they required replacing by new ones.

Mr. T. Forsyth thought that india rubber in hose pipes would be likely to last longer than in the packing rings, when exposed to the same circumstances of high temperature of the water, because of the rolling action to which the packing rings were continually subjected; for india rubber was generally deteriorated in its properties by exposure to any kneading action, and more liable to fail when subjected to that action than under simple compression or bending.

Mr. Siemens remarked that the vulcanized india rubber was manufactured at a high temperature, above 300° Fahr., and was not injuriously affected by exposure afterwards to a lower temperature; it proved very durable if its elasticity was not brought into action too severely, but a kneading action was very destructive by breaking up the cohesion of the mass. When not exposed to this source of injury he had known it last for many months in pump valves, even at a constant temperature of 150°.

Professor Rankine had used an india rubber ring to make a steam joint at as high a temperature as 550°, in a model where it was exposed to steam at about 1000 lbs. per inch, and it had stood well if undisturbed; but when the joint had been several times broken, the india rubber was found to fail. The high pressure was obtained in a small copper boiler, 3 inches diameter and $\frac{1}{2}$ inch thick, heated by gas to 550°, the pressure being measured and regulated by means of a thermometer, as no safety valve was employed. India rubber suffered great injury also from the effect of oil, which caused its substance to become disintegrated or broken up.

Mr. W. B. Johnson had found india rubber valves last many years in steam engine air pumps, where they were exposed to a considerable temperature, sometimes 150°, but the material was subjected only to simple bending.

The Chairman enquired what was the comparative cost of the new couplings and the ordinary brass ones.

Mr. Fenton replied that their cost was £2 per set as compared with about £12 12*s*. for the brass ball and socket couplings, being only about one-sixth in first cost; and there was also a considerable saving in cost of maintenance. The rolling action to which the packing rings were subjected did not appear to be injurious to their material, as they had already run upwards of 8000 miles without any sign of injury, although exposed to the heat of blowing steam into the tender in the ordinary manner.

The Chairman proposed a vote of thanks to Mr. Fenton for his paper, which was passed.

The following Paper, by Mr. C. William Siemens, of London, was then read:—

ON A NEW CONSTRUCTION OF FURNACE, PARTICULARLY APPLICABLE WHERE INTENSE HEAT IS REQUIRED.

The high importance of the stores of combustible material which are distributed upon the surface of the earth renders their wasteful expenditure and rapid diminution in quantity in many parts a serious subject for consideration; and in the writer's opinion there is no object more worthy of the earnest attention of engineers and men of science generally than that of causing the generation and application of heat to be conducted upon scientific and economical principles. Our knowledge of the nature of heat has been greatly advanced of late years by the investigations of Mr. J. P. Joule, of Manchester, and others; which have enabled us to appreciate correctly the theoretical equivalent of mechanical effect or power for a given expenditure of heat. We are enabled by this new dynamic theory of heat to tell, for instance, that in working an engine of the most approved description we utilise at most only one-sixth to one-eighth part of the heat that is actually communicated to the boiler, allowing the remainder to be washed away by a flood of cold water in the condenser. If we investigate the operations of melting and heating metals, and indeed any operation where intense heat is required, we find that a still larger proportion of heat is lost, amounting in some cases to more than 90 per cent. of the total heat produced.

Impressed by these views the writer has for many years devoted much attention to carrying out some conceptions of his own for obtaining the proper equivalent of effect from heat: some of the results he has obtained are known to the members of the Institution, amongst which are the Regenerative Steam Engine and Condenser, the Regenerative Evaporator, and an apparatus for the economic production of Ice. The regenerative principle appears to be of very great importance and capable of almost universal application; and the object of the present paper is to describe an application of this principle to furnaces of every description.

The invention of the Regenerative Furnace is due to the writer's brother, Mr. Frederick Siemens; and it has been matured and variously applied by the writer within the last few months. The

result has in all cases been a large saving in fuel over the plans in common use, amounting to from 70 to 80 per cent. of the total quantity of fuel hitherto consumed. The apparatus employed is moreover of a very simple and permanent description, and combines economy of fuel with other advantages, amongst which are the total prevention of smoke and a general improvement in the quality of the work produced.

Figs. 1 to 4, Plate 118, represent the new furnace in the form applicable to piling iron, or heating iron, steel, or other substances.

Fig. 1 is a longitudinal section of the furnace, and Fig. 2 a sectional plan; Figs. 3 and 4 are transverse sections.

The furnace consists of the heated chamber A, and of two fireplaces or solid hearths B and C, communicating respectively with the two regenerators D and E. Each regenerator consists of a series of walls of firebrick, laid in open Flemish bond, in such a manner that the pigeon holes of each wall are opposite the solid parts of the succeeding wall, the object being to form a number of zigzag or tortuous passages through the regenerators, leading to opposite sides of the valve F, shown dotted in Fig. 1, at the bottom of the chimney G. The valve F consists of a rectangular box of iron open at the two sides to the two regenerators D and E, at the bottom to the atmosphere, and at the top to the chimney G. A spindle passes through the centre of the two remaining close sides of the box, and carries a rectangular flap or moveable plate, fitting the box sideways and bearing against one of its upper and one of its lower edges, according to the position of the tumbling lever and weight H which are fixed upon the spindle outside.

When the valve is in the position shown dotted in Fig. 1, the atmospheric air entering from below proceeds in the direction indicated by the arrows, passing through the regenerator D, over the fireplace B, through the heated chamber A, over the fireplace C, through the regenerator E, and by the valve F into the chimney G.

A fire having been lighted upon the hearth B through the side opening K, the flame passes through the furnace and through the regenerator E to the chimney G. In its passage through the regenerator E, the first perforated wall that the flame strikes against will be heated to a considerable degree, the second wall to a lower degree, and so on in succession, the heat of the current being thoroughly exhausted by the time it reaches the chimney.

After about one hour's work the position of the valve F is reversed, and fuel is supplied through the opening L to the second

fireplace C, which is then acted upon by a current proceeding in the opposite direction to that indicated by the arrows. The cold atmospheric air comes in contact first with the least heated wall of the regenerator E, and then with the more heated walls successively, acquiring thereby a degree of temperature approaching the temperature of the heated current which previously entered the same regenerator. The heat thus imparted to the fresh air greatly increases the temperature of the flame which is now being produced upon the hearth C, and consequently the nearest end of the regenerator D will be heated also to an increased degree, the current reaching the chimney comparatively cool.

When the valve F is again reversed, the fresh air will be heated nearly to the increased temperature of the hot end of the regenerator D, and will produce a still hotter flame with the fuel supplied to the hearth B. It is evident that by a continuation of this process an accumulation of heat to any degree may be produced within the furnace, provided only the heat produced in combustion is greater than the heat lost by radiation and the heat absorbed by the metal or other substances in the heating chamber.

In the regenerative furnace now described, the temperature at which the heat is communicated to the materials does not affect the quantity of fuel requisite, except so far as increased radiation is concerned; for the products of combustion pass away in all cases at a temperature not above 200° or 300° Fahr. This new principle of furnace is therefore applicable with the greatest advantage in cases where intense heat is required. It has been applied to furnaces for reheating steel and iron, at the works of Messrs. Marriott and Atkinson at Sheffield. One of these furnaces has now been in constant work for nearly 3 months; and according to a statement received from Mr. Atkinson it has worked quite satisfactorily, and the result of a careful comparison has shown a saving of 79 per cent. to be effected over the old furnace in heating the same quantity of metal. Mr. Atkinson has also applied this principle of furnace for melting cast steel, and has obtained a still larger saving, although the new melting furnace has not yet been rendered entirely satisfactory for the workman.

The regenerative furnace has also been applied to the purpose of puddling iron; and though the new puddling furnace has been completed and worked only for a few days at the works of Messrs. Rushton and Eckersley at Bolton, the writer is able to state that it

converts a charge of 480 lbs. of pig metal into wrought iron with an expenditure of only 160 lbs. of common coal, as compared with 6 cwt. required in the ordinary furnaces: the net yield of wrought iron is higher than that of the ordinary puddling furnace, and the quality of the iron produced seems also to be superior. It is also worth mentioning that the chimney of this puddling furnace may be watched for hours, and no trace of smoke be seen issuing from it. Several other applications of this principle of furnace are contemplated by the writer, which it would be premature to enter upon on the present occasion.

Mr. Atkinson said he had been working a reheating furnace at the Fitzalan Steel Works near Sheffield during the last 2 months, the furnace having been altered to the new plan described in the paper; and had worked it for the time in juxtaposition with a corresponding ordinary furnace, both having been built originally at the same time and doing the same description of work, heating cast steel bars for rolling and tilting. He was so much surprised at the great difference in the consumption of fuel by the two furnaces, that he had a particular account kept of the consumption of both during the last week, and found the total consumption of each in the 6 days was 7 tons in the ordinary furnace and only $1\frac{1}{2}$ tons in the altered one, the work done by each being practically the same and all circumstances alike during the time of comparison. He had also made a trial of the new plan of furnace for melting cast steel, and obtained an equally favourable result as to economy of fuel; rather less than 1 ton of coke was consumed per ton of steel melted, instead of $3\frac{1}{2}$ to $4\frac{1}{2}$ tons per ton of steel as required in the ordinary melting furnaces. This last furnace was not yet got into regular work, as it was not quite complete in detail at present, and there were some minor difficulties to be surmounted to suit fully the requirements for managing cast steel; but the main difficultics had

been quite got over, and he saw no reason to doubt the complete success of the new principle of furnace; and the saving in cost of fuel was so very large that he fully expected the plan would become generally adopted for steel furnaces. He had found that the smoke was completely consumed in the new furnaces, and did not see why the same principle should not be applied to steam engine and other furnaces generally, effecting an important saving of fuel, and thoroughly removing the nuisance of smoke.

Mr. McConnell was much struck with the beautiful principle involved in the new furnace, of making the currents of air circulate alternately in opposite directions, and thus effectually extracting the heat from the air before it reached the chimney. He enquired whether it was found that the great alternation of temperature affected the durability of the brickwork, as the several portions were exposed to extreme variations of temperature; also whether there was any difficulty in keeping the holes in the regenerator walls open and in repair, on account of the very high temperature to which they were exposed.

Mr. Atkinson replied that he had not experienced any practical difficulty from that cause, but on the contrary he found an important saving in the cost of brickwork repairs: for in the ordinary furnaces the chimney had to be lined with firebrick to a considerable height, in consequence of the intense heat of the air entering the bottom of the chimney; but in the new furnace the heat was so completely extracted before reaching the chimney, that he could bear his hand on the flue within a foot of the valve at the base of the chimney that regulated the alternation of the current, and not a single firebrick was now used in the chimney. In the regenerator portion of the furnace there was no sign of want of repair at present, nor of slag from the melting of the bricks, and they appeared likely to last three times as long as they had done at present.

Mr. Siemens considered the durability of the brickwork might be fully accounted for by the circumstance that, on attaining the very high degree of temperature, the air had first to heat the ends of the first wall of bricks that it met with to a very intense degree, but the next wall to a less degree, and so on gradually diminishing towards the chimney. It might be expected at first that the cold air entering would have a tendency to crack the hot bricks; but it should be remembered that the air became gradually heated as it advanced, coming in contact at first with a comparatively cool wall, and afterwards by degrees with hotter and hotter walls, taking up

only about 100° or 200° of temperature from each successive wall, each one being only a little hotter than the air on reaching it. There was consequently no sudden difference of temperature at any point between the air and the brickwork with which it came in contact, and all risk of sudden chilling and cracking of the brickwork was thus avoided. The alternating principle of the furnace gave a remarkable result in the extremely high degree of temperature that could be ultimately attained, as each repetition of the process added something to the previous temperature of the furnace, the heat continually accumulating; and if the surface were sufficiently covered to prevent loss of heat by radiation, it would be possible by continuing the alternation to attain a temperature far higher than in any existing furnace, and limited only by the materials employed.

Mr. Fenton asked how far the application of the new principle of furnace to puddling iron had proved successful at present; and in what way it was considered that any improvement in the quality of the iron could be effected by the process.

Mr. Siemens replied that he had not yet had any long experience of the application of the plan to puddling, but from the results already obtained he thought there was full reason to anticipate its entire success. This case was a peculiar one from the necessity of keeping the puddling door open during the process, the furnace being consequently exposed to the open air; and some modifications were therefore required in the details, which only the experience of further trials could enable them to get fully matured; there were also difficulties to be overcome in the working on the part of the men, from the great contrast to their accustomed working of puddling furnaces, so much smaller quantity of fuel and so much less draught being required. Besides the saving in fuel, he expected a decided advantage both in the quantity and the quality of the iron made, by removing the violent draught produced by the intense heat of the chimney in the ordinary puddling furnaces; the comparatively cold chimney in the new furnace, with the damper lowered to within 2 inches of the top of the chimney, gave so small a draught that the flame did not cut the iron and waste it as in the ordinary furnace, a higher temperature being obtained with a more quiescent atmosphere. There was also the advantage that no flame or particles of fuel were carried over the surface of the iron, bringing sulphur and other impurities from the firegrate.

The Chairman remarked that the use of so much less fuel would also so much reduce the quantity of impurities present.

Mr. McConnell thought the equable temperature would give an important superiority for puddling furnaces and all heating furnaces, and there would be also the advantage of freedom from smoke as well as impurities; he thought the new principle of furnace was likely to open a very wide field of application.

Mr. Atkinson observed that the regularity of heat was found to be remarkably improved by the new furnace when properly managed; there was some difficulty in getting the proper management at first, from the great contrast to the ordinary furnaces, but it was very simple when once fairly established. The heat was got up gradually at first, and rather slower than in ordinary furnaces, but when once up it was maintained with ease at a higher temperature than was practicable in the ordinary furnaces, and with complete regularity; thus avoiding the frequent check occasioned by the ordinary heavy firing and opening of the firedoor, which let in a rush of cold air and caused great irregularity of temperature in the ordinary furnaces.

Mr. T. Forsyth asked whether any practical difficulty was found to arise from accumulation of residuum upon the walls of the regenerator, choking up the interstices and requiring removal; also what was the comparison in point of time of the process of puddling.

Mr. Siemens replied that the ashes had to be cleared out frequently, but they were readily removed through the holes provided for the purpose at the back of the furnace, and the puddler simply raked them out on putting a fresh charge into the furnace. The new furnace was found to puddle the iron in about the same time as the ordinary ones, a charge being brought out about every 2 hours if the fires were sufficiently attended to. It took rather longer to get up the heat at first, but the furnace retained the heat longer and a higher temperature was obtained; one night's stoppage required about the same time as the ordinary furnace to get up the heat again in the morning, but a longer stoppage would cause a somewhat longer time to be required. The principal difficulty experienced in working was from the men putting on too much coal at once, being accustomed to the necessities of the old furnace, and thus choking the fire and retarding instead of accelerating the working of the furnace.

Mr. Henry Maudslay was much pleased with the principle of action of the new furnace, which was certainly very ingenious and mechanical, and made a remarkable advance in the means of

economising fuel; he thought at first that a collection of soot would be liable to form in the interstices of the regenerator and impede its action, but that appeared not to be a difficulty experienced in practice. He was very glad to see any plan brought out that tended to effect the consumption of smoke, which was an object highly important to be satisfactorily accomplished. There was a simple plan at work for consuming the smoke of a balling furnace attached to a steam hammer, which had been found to give a saving of fuel and a great advantage in working. It was a closed furnace, having the air admitted near the foot of the chimney, and passing under the bed of the furnace, where it got heated before passing up through the grate; a more perfect combustion was effected by this means, scarcely any smoke was produced, and a decided economy of fuel was effected. This furnace had been about 8 months at work, at Messrs. Maudslay and Field's in London, and was only now under repair for the first time.

Mr. Cochrane considered that, in reference to the application of the new principle of furnace to puddling, the question as to the time required for bringing the iron to nature was of great importance to the production of the iron; and also whether the new furnace could be worked with the same regularity as the present ones, without depending too much on the care and constant attention of the men. Unless great regularity in the action was obtained, and no longer time required for the process, expense would be occasioned by needing an increased number of furnaces to get through the same amount of work, which would counterbalance the saving in fuel. The new principle of furnace was undoubtedly a very important one to be fully considered and tried; and if it could be successfully brought into general use, it would have an important effect on the iron trade and all consumers of wrought iron, by diminishing the cost of manufacture.

Mr. Siemens said that the experience with the new puddling furnace was too limited at present to determine fully the difference in the time of the process; in the furnace now working at Bolton it was found that the iron was about 10 minutes longer in melting down, but was rather quicker in coming to nature than in the ordinary puddling furnaces; and there was no decided difference in the whole time of working. Some difference in management from the ordinary furnace was of course required, which caused a difficulty at first in carrying out the new plan; but the principle of the furnace was quite simple, and no more skill and care was needed

than was to be looked for in the men concerned. The quantity of fuel consumed and amount of firing required were much less; and by keeping the fire low a large proportion of oxygenated air was allowed to enter during the puddling process, which was supplied at a very high temperature, preventing fluctuations in the temperature of the furnace; and the very low draught of the chimney was an important point in greatly reducing the quantity of cold air unavoidably drawn in at the puddling door whilst open during the process.

Mr. Ramsbottom asked whether it was thought the principle of the new furnace would prove applicable to steam engine furnaces; he did not see how it could be practicable to obtain any material advantage in that case by the application of this principle, as the heat being absorbed by the boiler and carried off in the shape of steam could not be available for regenerative purposes; the air was already cooled down to a comparatively low temperature before entering the chimney.

Mr. Siemens said he had not attempted that application of the principle at present, the trials having been first made in those kinds of furnaces where the highest temperature was employed, and where consequently the greatest economy could be effected by the regenerative plan; but even in the case of steam boilers, a considerable portion of the fuel was generally wasted, by the air being allowed to escape into the chimney at a higher temperature than was required for the purpose of maintaining the draught.

The Chairman proposed a vote of thanks to Mr. Siemens for his paper, which was passed; and expressed a wish that he would communicate on a future occasion the further results of the application of the furnace.

The Chair was then taken by William Fairbairn, Esq., Vice-President.

The following Paper, by Mr. William Menelaus, of Dowlais, was then read:—

DESCRIPTION OF THE LARGE BLOWING ENGINE AND NEW ROLLING MILL AT DOWLAIS IRON WORKS.

The large Blowing Engine and Rolling Mill forming the subjects of the present paper are remarkable particularly for their great size, the blowing engine being the largest of its class hitherto erected either in this country or abroad; and were designed with a view to turning out a large quantity of work with the greatest possible security from risk of failure or deficiency of the blast or of breakage of the machinery.

The Blowing Engine was erected in 1851, and is shown in Figs. 1, 2, and 3, Plates 119 and 120. Fig. 1 is a side elevation of the engine, and Fig. 2 an end elevation. Fig. 3 is an enlarged vertical section of the blowing cylinder.

The blowing cylinder A is 144 inches diameter with a stroke of 12 feet, making 20 double strokes per minute, the pressure of the blast being $3\frac{1}{4}$ lbs. per square inch. The discharge pipe B is 5 feet diameter and about 140 yards long, thus answering the purpose of a regulator. The area of the entrance air valves is 56 square feet, and of the delivery air valves 16 square feet. The quantity of air discharged at the above pressure is about 44,000 cubic feet per minute.

The steam cylinder C is 55 inches diameter and has a stroke of 13 feet, with a steam pressure of 60 lbs. per square inch, and working up to 650 horse power. The steam is cut off when the piston has made about one-third of its stroke, by means of a common gridiron valve D near the back of the slide valve E, as shown enlarged in Figs. 4 and 5, Plate 120; there is also on one side of the nozzle a small separate slide valve F for moving the engine by hand when starting. The cylinder ports are 24 inches wide by 5 inches long, and the slide valve E has a stroke of 11 inches with $\frac{1}{2}$ inch lap. The engine is non-condensing, and the steam is discharged into a cylindrical heating tank, 7 feet diameter and 36 feet long, containing the feed water from which the boilers are supplied. Under the steam cylinder C there are about 75 tons of cast iron framing G, and 10,000 cubic feet of limestone walling in large blocks, some of them weighing several tons each.

The beam H is cast in two parts of about $16\frac{1}{2}$ tons each, the total weight upon the beam gudgeons being 44 tons; it is 40 feet 1 inch long from outside centre to outside centre, and is connected to the crank on the flywheel shaft I by an oaken connecting rod K strengthened from end to end by wrought iron straps. The beam is supported by a wall L across the house, 7 feet thick, built of dressed limestone blocks, to which the pedestals M are fastened down by twelve screw bolts of 3 inches diameter. The flywheel I is 22 feet diameter, and weighs about 35 tons.

Eight Cornish boilers are employed to supply the steam, each 42 feet long and 7 feet diameter, made of $\frac{9}{16}$ inch best Staffordshire plates, and having from end to end a single 4 feet tube in which is the firegrate 9 feet long.

For some time this engine supplied blast to 8 furnaces of large size, varying from 16 to 18 feet across the boshes; it is now blowing, with three other engines of small dimensions, 12 furnaces, some of which make upwards of 235 tons of good forge pig per week, the weekly make of the 12 furnaces being about 2000 tons of forge pig iron. With the exception of the cylinders, made and fitted at the Perran Foundry, Truro, this engine and boilers were made at the Dowlais Iron Works, and erected according to the design and under the superintendence of Mr. Samuel Truran, the Company's engineer.

The engines for driving the new Rolling Mill now in course of erection at the same works are a pair of high pressure engines coupled at right angles, shown in Figs. 6 and 7, Plates 121 and 122. Fig. 6 is a side elevation, and Fig. 7 an end elevation of the engines. Fig. 11, Plate 123, is a general plan of the rolling mill to a smaller scale.

The steam cylinder C is 45 inches diameter with a stroke of 10 feet, making 24 double strokes per minute. Each cylinder has a common slide valve of brass worked by an eccentric on the main shaft. The expansion valves are of the gridiron sort, worked by a cam on the main shaft, the steam being cut off at about one-third of the stroke; an arrangement is made for throwing these valves out of gear when the engines are doing heavy work. Each engine is furnished with a small slide valve to be worked by hand for the purpose of starting and reversing. The steam is supplied by six Cornish boilers, 44 feet long and 7 feet diameter, having a 4 feet tube in each; the whole of the plates are best Staffordshire $\frac{9}{16}$ inch thick, and the total weight is 120 tons.

The framing G under the engines and machinery is of cast iron, and consists of four lines, each 75 feet long, 12 feet high, and 21 inches wide; the whole weighing about 850 tons.

Each beam H is in two parts, the sides weighing about 17 tons, making the total weight of each beam when complete about 37 tons. The two beams are supported upon eight columns L, 24 feet long and $2\frac{1}{2}$ feet diameter, securely fastened at the bottom in deep jaws cast upon the framing. Upon the top of each group of four columns is a large and heavy entablature plate N, which carries the plummer blocks M under the main gudgeons. Each column passes through the entablature, the bosses at the junction being 24 inches deep; these are bored and the tops of the columns turned so as to ensure a perfect fit. The plummer blocks M are secured by wrought iron keys in jaws cast on the entablature N in the usual manner. The connecting rods K are of oak with wrought iron straps.

The driving wheel shaft I is of cast iron with bearings 24 inches diameter; the flywheel shaft O is also of cast iron with bearings 21 inches diameter. The diameter of the driving wheel is 25 feet to the pitch line, width on the face 27 inches, and pitch 7 inches. The diameter of the spur wheel or pinion on the flywheel shaft is 6 feet, and the teeth are strengthened by a flange running up to their points on each side. The flywheel O on the mill shaft is 21 feet diameter and weighs about 30 tons, making upwards of 100 revolutions per minute. The whole of the fastenings both of the wheels and framing are of dry oak and iron wedges, as shown enlarged in Figs. 8, 9, and 10, Plate 121.

These engines will drive one rail mill capable of turning out 1000 tons of rails per week, another mill capable of making 700 tons of rails or roughed-down per week, and one bar or roughing-down mill capable of making 200 tons per week; they will thus readily turn out 2000 tons of iron per week. Two blooming mills with three-high rolls and two hammers will also be worked by the same engines. The saws and small machinery will be driven by separate engines, as will also the punching and straightening machines.

The roofs cover a space of 240 feet by 210 feet, and are to be covered with corrugated black plates of No. 14 wire gauge thickness. The span is 50 feet, the roofs being supported upon lattice girders of an average length of 45 feet. The position of the columns is shown on the ground plan, Fig. 11, Plate 123; and it will be observed that the entire mill floor is free from obstruction. The flooring will be of cast iron plates 1 inch thick.

It has long been felt that the power of rolling wrought iron of large section and great lengths has not kept pace with the requirements of engineers, who are hampered in their designs by the impossibility of obtaining iron of sufficient dimensions. For engineering works of any magnitude, bars of great length, considerable width, and moderate thickness, are frequently required. In the ordinary mode of rolling, the length and width of the bar are measured by the power of the engine and the time occupied in rolling. It is obvious that to finish a bar quickly it is necessary that it should be rolled in two directions to prevent delay; and long and heavy bars can be thus rolled only by an engine of enormous power. This object is designed to be attained by the large combined engines now described. A simple arrangement of rolls for working in two directions is shown in Figs. 12, 13, and 14, Plate 123; the lower pair of rolls P is driven from the flywheel shaft, and under ordinary circumstances will be worked in the usual manner, rolling the bars in one direction and lifting them over the top roll in coming back. When it is necessary to make extra sized bars the rolls RR will be put in the standards, and driven from the flywheel shaft by the pair of wheels SS, Fig. 6, Plate 121, thus giving the means of working the iron in both directions, as shown by the arrows. By this arrangement the mill is expected to be able to roll iron of such sections and lengths as have been hitherto unattainable.

Mr. E. Jones said he had had an opportunity of seeing the large blast engine at work at the Dowlais Iron Works, and was much struck with it. It was a very remarkable and interesting sight to see 40 tons of iron in the main beam moving at the high speed of 520 feet per minute at the extremities, a much greater speed than had been contemplated when the engine was first erected. The whole working of the engine was so smooth and quiet, that its great magnitude was not apparent at the first glance.

Mr. McConnell thought the engine was one of great interest, and the excellent drawings that were exhibited of it would form a valuable addition to the collection in the Institution; he hoped that some indicator diagrams from the engine would be also supplied, as they would be of particular value from an engine so remarkable for size and speed.

Mr. Menelaus said he would be happy to supply diagrams of the working of the engine; it had now continued regularly working six years without any failure, and had proved very satisfactory.

The Chairman observed that the engine appeared not to be a condensing one, and enquired the reason for such an engine being made non-condensing.

Mr. Menelaus replied that a high pressure non-condensing engine had been adopted, because of the difficulty in getting a sufficient supply of water for condensing in that situation; it was worked with 60 lbs. steam, expanding through about 2-3rds of the stroke.

The Chairman asked whether the waste gases from the blast furnaces were used for heating the steam boilers.

Mr. Menelaus replied that they did not make use of the waste gases for that purpose, not having been able as yet to get a completely satisfactory result from their use; raw coal was used in most of their furnaces with cold blast, and was not so suitable as in other cases for taking off the waste gases from the furnace; the make of the furnaces was very large, as much as 235 tons per week being obtained from one furnace working with raw coal and cold blast.

Mr. Henry Maudslay observed that an oak connecting rod was used in the engine, and enquired the reason for its adoption, as he was surprised to see that construction in an ironworks, all the rest being so massive.

Mr. Menelaus said the result of 40 years' experience had led them to prefer oak with wrought iron straps, having found it the best on the whole for the purpose. A cast iron connecting rod was liable to break, and it was of particular importance to guard against risk of breakage, as the consequences of such an accident would be very serious; and wrought iron would be very expensive when of that extreme size. They found the oak connecting rod very durable, and easy to repair, whilst it was a much less expensive construction and considerably lighter than iron.

Mr. Cochrane enquired what was the total weight of metal in the two engines described, as they appeared to be very massive in their proportions and considerably stronger than they would be by the usual calculations.

Mr. Menelaus replied that the blowing engine of 650 nominal horse power weighed about 300 tons, including the bed-plates; and the pair of rolling mill engines of 1000 nominal horse power would have about 1000 tons of metal in them. These were probably

nearly double the ordinary proportions; but it was their practice to make their engines very strong, and they generally put in three times the calculated weight of metal, as it was of the first importance to them to have no stoppages of the works from any break-down of the engines. They expected their engines when once fairly started to go on working week after week without stoppage or delay, and expense of construction was not a consideration compared with this object; if they could arrive at a machine that would never break, it would be considered perfection.

The CHAIRMAN asked what was the object of having the set of four rolls that was shown in the new rolling mill.

Mr. MENELAUS said that the limit as to length in making very large bars of thin section was the time required for the rolling, as they had to be completed at one heat, in consequence of the impossibility of getting such long bars into the furnace to reheat; in the ordinary rolling so much time was lost in bringing back the bar over the top of the rolls that it was found impossible to make the larger sizes that were wanted in modern work. The plan was therefore contrived of having a second pair of rolls running in the opposite direction, placed at the back of the first rolls, the lower one of the second pair being raised just enough above the upper one of the first rolls to clear the bar in coming through; and the bar was passed back through the second rolls as readily as over the top roll in the ordinary arrangement. By this plan half the time was saved, and the rolls were all as handy for adjustment as the ordinary ones; and they gained the great advantage of being enabled to manufacture bars up to 60 feet length for deck beams and keels of iron ships in one length without a weld. They had rolled already quite successfully bars 46 feet long and 10 inches wide and only ½ inch thick, and expected to go up to 60 and even 70 feet length when the new rolling mill was got to work; the only chance of rolling such extreme lengths was by having a high speed of the rolls, so as to complete the work before the bar got too cold, and this necessitated the great power of the engines described, as the full power required for rolling had to be exerted at this increased speed.

Mr. COCHRANE remarked that reversing gear had been very successfully employed at the Patent Shaft Works, Wednesbury, for rolling long links for suspension bridges; the motion of the ordinary rolls being reversed by a lever shifting an ordinary reversing clutch, the engine shaft running always one way, returning the bar through

the rolls in the opposite direction without any delay and without requiring it to be lifted at all; this plan had been at work several years with complete success, and was a more simple arrangement than the double set of rolls now described.

Mr. Menelaus replied that the objection to reversing gear was that it limited the speed at which the rolls could be driven, and he believed that it was not found applicable to rolls running above 45 revolutions per minute, on account of the violent shock in reversing the motion at a higher speed. They were obliged to employ a much higher speed in order to roll the lengths contemplated, and were working at nearly three times that speed at the Dowlais Iron Works; the ordinary rail rolls running at 120 revolutions per minute, and the other rolls for large sections at 110 revolutions, the rolls being of the full ordinary size, 21 inches diameter. He considered the speed of 120 revolutions per minute was necessary to obtain the long bars of $\frac{1}{2}$ inch or even $\frac{3}{8}$ inch thickness that were now required to be made, and they had now doubled the speed of the old Welsh rail mills which was only 60 revolutions per minute.

Mr. Cochrane asked whether the quality of the bars was interfered with by the increase in speed, and whether the rolls running at such a high speed turned out as good work.

Mr. Menelaus did not know of any necessary difference in the quality of the bars on account of the speed; an inferior quality of iron was found to stand the rolling better at the high speed than at the old speed.

The Chairman remarked that several specimens of wrought iron of great section and weight were shown at the Paris Exhibition, of French manufacture, which showed that an important advance had there been made over what had previously been practicable. It was a great desideratum to avoid the necessity for angle iron in the deck beams for iron ships and similar constructions, by getting the iron rolled complete with the required flanges, and also to obtain the beams in one length without a joint; and the new rolling mill that had been now described appeared to be a highly important step in accomplishing that object. He thought the paper was a very interesting and valuable one, and proposed a vote of thanks to Mr. Menelaus, which was passed.

The following Paper, by Mr. George Tosh, of Maryport, was then read:—

ON THE RELATIVE EVAPORATING POWER OF BRASS AND IRON TUBES.

Brass and Iron Tubes for locomotive, marine, and other boilers, having been so extensively employed, their respective properties and defects are generally known under the various trying circumstances and situations in which they have been used; but as there is still a difference of opinion existing on the subject of their relative advantages, the following experiments were made by the writer with great care, for the purpose of arriving at the truth if possible and for his guidance, as to the relative evaporating power of brass and iron tubes.

The writer having had the superintendence of locomotive and other engines for a number of years, has used considerable numbers of both brass and iron tubes, in several cases with apparently equal success: the former have generally been preferred for locomotive engines working at a high pressure, because there is less difficulty in keeping them fast in the tube plates, and the adhesion of the deposit from bad water is not so great on brass as on iron; and it is well known that when iron tubes once become leaky, their ends are speedily wasted and cannot afterwards be depended upon. Although brass tubes are generally adopted by the railway engineers of England, in preference to iron, there are companies using iron ones largely at the present time; and some engineers express their surprise at any other material than iron being used for that purpose.

Some time ago the writer's attention was drawn to a paper on this subject in the American Railroad Journal, from which the following is an extract:—"It has been for many years and still is the practice of scientific men, to recommend copper in preference to wrought iron, for boilers to heat water or other fluids, on the ground of the superior conducting power of the former over the latter metal; and it will doubtless appear strange to many that a doctrine so well established should now meet with the most unqualified dissent. The superior conducting power of copper over iron admits of no doubt; and yet, upon this correct basis, has been raised a fallacious doctrine

resulting in a great waste of money by the use of copper instead of iron in the boilers of steam boats and locomotives. Iron absorbs heat so much more rapidly than copper, that many explosions have occurred, which would not, had copper been used; although this is admitted, it is too bad to praise copper for this also, that it will not let a boiler blow up, when everything considered it ought to blow up, if a good fire and a good medium through which to convey its caloric into the water have any virtue in them. Copper cannot be a good medium through which to raise steam and a bad one to blow up with; yet the argument means this if anything: nevertheless it is admitted that this is not the ground on which any dependence can be placed; because whenever such a catastrophe has happened, it has arisen from a defective arrangement of the boiler, in fact the greatest defect that can properly occur in the designing of a boiler, the want of a complete and thorough circulation of the water within it, on precisely the same principle as the circulation of hot water in pipes for the purpose of warming buildings."

As these views are so directly at variance with the general views of the engineers of this country, the writer determined on making experiments for himself, being unable to obtain any information on the subject that could be relied on. Two vertical boilers A, Figs. 4 and 5, Plate 117, were therefore constructed of equal dimensions, 6 inches diameter and 2 feet long, with a single tube B in the centre of each, 2 inches external diameter and No. 14 wire gauge thickness, of brass and iron respectively. The two boilers were filled with water of the same quality and of the same temperature, and alternately placed upon a stand in the same position over a gas flame C; they were each exposed to the action of the gas for the same length of time, which was equivalent to the same quantity of fuel being consumed in each case; and the height of water was carefully gauged after each experiment as soon as ebullition had ceased. The experiments were first made during the day, and afterwards at night, at times when there was the least probability of a change of pressure in the gas pipes during the period of the experiment, by lighting or extinguishing the gas in the town.

The annexed Table shows the results of eight experiments made with the above apparatus, the quantity of water evaporated being measured by the number of inches that the level of the water in the boiler is lowered in each experiment: the average shows that 2 lbs., cwts., or tons of fuel with brass tubes evaporate the same quantity of water as $2\frac{1}{2}$ lbs., cwts., or tons of the same fuel with iron tubes;

hence the evaporating power of brass is to that of iron as 125 : 100, or brass will evaporate about 25 per cent. more water than iron with the same quantity of fuel.

Table of Experiments
on the Relative Evaporating Power of Brass and Iron Tubes.

Description of Tubes.	Quantity of Water Evaporated.								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Average.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Brass ...	2	$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{8}$	3	$3\frac{1}{4}$	$3\frac{1}{4}$	3	$2\frac{1}{2}$
Iron ...	$1\frac{5}{8}$	$\frac{3}{8}$	2	$1\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{4}$	2

Further experiments were made with brass and copper tubes, and copper was found to be fully as much superior to brass as brass is to iron; so that the evaporating power of copper is to that of iron as 156 : 100, or copper will evaporate about 56 per cent. more water than iron with the same quantity of fuel.

Mr. McConnell enquired whether the two sets of tubes used in the experiments were exactly the same gauge in thickness, since a little difference in that respect would sensibly affect the result of such experiments, as they were on a small scale compared with actual practice.

Mr. Tosh replied that the tubes were gauged as exactly as possible, special care being taken to make sure of having the same thickness in all; the water was also gauged when cold in each case to avoid any error from expansion of the water; and from the precautions taken to prevent sources of error in the experiments, the results obtained could be attributed only to the different conducting power of the two metals.

Mr. W. B. Johnson asked how the uniform pressure of the gas throughout all the comparative experiments had been ensured, and whether a meter had been used to measure the consumption exactly, as the quantity consumed might vary so much with ordinary variation of pressure as to affect the results materially.

Mr. Tosh said the consumption of gas had been regulated only by having the same burner burning for the same length of time. Measuring the quantity by a meter would certainly have been more complete; bnt he thought from the precautions taken there could not be any perceptible error from that cause; application was made to the gas works at the time of the experiments, and a uniform pressure ensured during the time they were in progress, which was only half an hour on each occasion.

Mr. W. B. Johnson was much surprised at the result obtained from the experiments, as it was quite different from the results of his own experience, and he had been led to the conclusion that there was no appreciable difference between the two metals in effective evaporating power. He had had a good opportunity of comparing them on a large scale in two boilers of 160 horse power each, which had been made exactly alike, except that one had iron and the other copper tubes; and the result of their working was found to be so equal that no difference could be decided upon between them. He enquired whether in the experiments described each pair of experiments that were compared together were made at the same time.

Mr. Tosh said that each pair of experiments were made not at the same time but immediately following each other, first the brass tubes and then the iron tubes, forming the pair for comparison; and then the same alternation again. He was now preparing for carrying out the experiments on a large scale, and hoped soon to obtain more extensive results; in all the experiments that he had tried, iron and brass only were employed, not copper, as his object was to ascertain the relative value of tubes made of iron and brass.

Professor Rankine observed that a number of experiments had been tried many years ago by Mr. James R. Napier with experimental boilers of iron and copper of various thicknesses heated over the same gas flame, and he found only a small difference in evaporating power of about $\frac{1}{20}$th or $\frac{1}{30}$th in favour of the copper. In all experiments of the kind the state of the heating surface was important, whether smooth or rough, and whether perfectly clean or incrusted to any extent. The effective evaporating result or transmission of heat through the metal depended on three properties: —1st, the resistance of the first surface to absorption of heat from the heated air and gases;—2nd, the resistance of the internal particles of the metal to the conduction of heat;—and 3rd, the resistance of the second surface to giving off heat to the water:— those three properties were not possessed in the same proportion by

different bodies; the resistance to internal conduction was less in copper than in iron, but the resistance of the surface was greater in copper. Peclet found, in one of the best series of experiments on the subject yet made, that when the surface became dull the transmission of heat through all metals was very nearly the same.

Mr. Siemens thought the difference was so great and so uniform in the results obtained from the experiments described in the paper, that it could not be accounted for by any unobserved variation in the quantity of the gas consumed, as that would not have caused a marked difference all on one side; he thought the experiments did not afford a true criterion of what brass and iron tubes would do in a locomotive boiler, as the mode of action and the currents of heated gases differed so much in these vertical tubes heated by gas flames below from those in the numerous horizontal tubes of a locomotive boiler. With the small gas flame, the air before coming in contact with the sides of the tube might be cooled down nearly to the temperature of the water, and the relative effect of resistance at the surface of the metal and in the interior would be materially altered, a low temperature leaving but little difference between the two bodies to overcome the resistance; the proportion of air carried through the two sets of tubes might also be varied by the effect of the temperature on the draught. The brass tubes might gain an advantage from their smoother surface causing less adhesion of the minute bubbles of steam during slow ebullition, though that circumstance would not apply in rapid ebullition. The internal conducting power of copper had been proved by Dr. Ure's experiments to be so good that the thickness of the metal did not perceptibly retard the rate of evaporation, though with iron the result was decidedly affected by the thickness.

Mr. R. Roberts thought the trial of the converse experiment of the time of cooling from the boiling point in two similar vessels of copper and of iron might be serviceable. He had found that the thickness of metal with copper as well as with iron materially affected the evaporating power, and that the thickness of plate when considerable much retarded the passage of heat, and caused the metal to be injured by overheating, the heat not being carried off by the water fast enough; he had found brass tubes of No. 18 wire gauge last considerably longer than others of No. 14 wire gauge under the same circumstances, and supposed that was owing to their transmitting the heat to the water more quickly, and therefore the metal suffered less than in the thick tubes.

Mr. Hawkes suggested the trial of corresponding experiments with tubes made of brass, copper, and iron, the lengths of which should be inversely as the conducting power of the metal.

Mr. Craig thought the temperature should be also tried in the experiments by a thermometer put into the tubes; the circumstances were certainly different in the experiments from those in locomotive boilers, in consequence of the exposure of the experimental tubes to currents of air. He had not found much difference in practice between brass and iron tubes in locomotive boilers, and did not know any definite result in favour of either of them as to evaporating power.

Mr. Henry Maudslay observed that in steam engine boilers, particularly marine and stationary, there were often other reasons affecting the question of the use of copper or iron, besides merely the conducting power for heat; such as durability under exposure to rusting or corrosion, and the relative accumulation of incrustation. He had known a case of nine marine boilers ordered for Naples, of copper, to allow of laying up without suffering from rust; for iron boilers were sometimes seriously damaged in 18 months, whilst copper boilers were not affected; and this became then a more important question than original cost or conducting power.

The Chairman proposed a vote of thanks to Mr. Tosh for his paper, which was passed; and expressed a wish that he would communicate on a future occasion the results of his further experiments.

The following Paper, by Mr. William B. Johnson, of Manchester, was then read:—

DESCRIPTION OF AN APPARATUS FOR THE PREVENTION OF SMOKE IN STEAM BOILER AND OTHER FURNACES.

Although it is generally admitted by those using steam boilers, that introducing cold air for the prevention of smoke may be made to effect that object, yet there is a general impression that this is effected only at the expense of a loss in the consumption of fuel. The object of the present paper is to show that smoke from steam boiler and other furnaces may be prevented with an economy in fuel, instead of causing a loss; and the experiments made by the writer, described in the present paper, appear to prove satisfactorily that by judicious arrangement cold air may be admitted into the furnace so as effectually to prevent the production of smoke, and at the same time cause the gases given out from the furnace to produce a more intense heat in their combustion, and to that extent economise the consumption of fuel.

The air, to be most effectual for the prevention of smoke, should be admitted in such a position relative to the furnace as to cause the whole of the products of combustion to come under its influence; and it should be admitted also in such increased or diminished quantities as the varying amount of gases produced may require.

The boiler to which the apparatus described in this paper is applied is of the multitubular construction, a form that presents more difficulty to the prevention of smoke than the various kinds of flue boilers. This boiler is of 30 nominal horse power, and is shown in Plate 124. Fig. 1 is a longitudinal section, and Fig. 2 a transverse section of the boiler. The shell A is 6 feet diameter by 14 feet long; the furnace B is 2 feet $10\frac{1}{2}$ inches diameter by 12 feet long, and is attached to the chamber C, 1 foot 7 inches long; there are 35 tubes, $3\frac{1}{4}$ inches diameter, leading from the chamber C. The firegrate is 7 feet long, and the top of the bridge D is 9 inches from the top of the furnace, and is level across the top.

Between the shell of the boiler and the top of the furnace is fixed a vertical wrought iron tube E, 7 inches diameter inside; this is placed directly over the furnace bridge D, and through it air is admitted to act upon the products of combustion passing from the furnace over the bridge. On this tube is placed a self-acting apparatus by which the admission of air is regulated, as shown in

section in Fig. 3. F is the outer casing, G a cylinder containing water, H an annular space through which air passes to the tube E. I is the valve cover, to the underside of which is fixed the air retainer K; and L is a regulating valve by which air is allowed to escape from the retainer K.

The action of the apparatus is as follows:—when the furnace door M is opened for firing, the chain N attached to it, passing over the pulleys OO and connected to the bell-crank lever P, lifts the cover I of the valve together with the air retainer K above the surface of the water contained in the cylinder G. When the furnace door is shut, the valve cover I falls until the air retained in the air retainer K causes it to float upon the water, in which position air is allowed to pass down to the furnace. The regulating valve L in the cover I is adjusted by means of a small screw, so that the valve cover may close or rest upon its seat in 5 or 10 minutes' time, more or less as may be required by the mode of firing adopted, and thus stop the supply of air to the furnace.

The advantages of this apparatus are considered to be, that the air being admitted in a downward direction does not beat the flame against the furnace plates and injure them, as is the case when it is admitted in an upward direction. The opening for admitting air cannot be choked up with dust or ashes from the furnace. Air is admitted at a part where the whole of the products of combustion are compelled to pass, and where they are most concentrated. The supply of air gradually diminishes from the time of firing, and ceases altogether when the supply obtained through the firegrate is sufficient to produce complete combustion. The furnace fittings are as simple as those of an ordinary furnace, and therefore are not more liable to get out of order. The self-acting valve for admitting air is simple in construction, no packings or accurate surface fitting being required; and the apparatus is worked by the fireman without any extra duty whatever beyond that required for an ordinary furnace.

The results of the experiments made with this apparatus applied to the boiler described have proved that smoke was effectually prevented by its use. During the experiments the process of combustion of the gases was observed through an opening made in the back chamber; and it was found that immediately after firing a dense black smoke was produced if the valve was closed, which was instantly replaced by a light white flame when the valve was opened, and so continued as long as the valve was opened to its proper extent; but if closed too soon, as was frequently done for experiment,

dense black smoke was again produced. Similar results were observed at the chimney top, except that the transition from dense smoke to no smoke was not so instantaneous as in the chamber, on account of the length of flues to be traversed before reaching the chimney top.

A pyrometer has been attached to the boiler for the purpose of ascertaining whether the use of this smoke prevention apparatus was attended with an increased production of heat. Through the centre of the boiler tube R is placed an iron rod S, $\frac{1}{4}$ inch diameter, secured at the exit end of the tube by a small cross bar; the other end is extended through the chamber C to the outside of the boiler shell, and is fixed to a spring by which it is kept in tension, being at the same time at liberty to expand or contract. Close to this spring a lever is attached to the rod S, the longer end of which marks upon a flat surface T to an enlarged extent by means of a pencil the degree of expansion or contraction the rod undergoes under various temperatures. The surface T upon which the pencil acts is caused to move slowly in a vertical direction at right angles with the movement of the lever, which thus describes an indicator diagram. This vertical motion is obtained by means of a small cylinder U, $2\frac{1}{2}$ inches diameter and 9 inches stroke, fitted with a piston and filled below with water, which escapes gradually through a small orifice, allowing the piston to descend with a uniform motion regulated in speed by the area of discharge, which is adjusted by means of a screw. From the position of the iron rod S in the boiler it is fully exposed to be acted upon by the varying temperatures of the gases passing from the furnace.

Fig. 4 represents a diagram described by the pyrometer. The pencil of the instrument was at A when the firedoor was shut, the air valve being open; at B the air valve was closed, at C it was opened, at D it was again shut, and at E was again opened, and the pencil rested at F, the diagram being completed. The horizontal lines represent equal intervals of the time of the vertical motion; the vertical lines represent equal amounts of increase of temperature as indicated by the advance of the pyrometer. It may be assumed that if the air valve had continued open throughout, the dotted line BDF would have been traced by the pencil; also that if the air valve had continued closed throughout, the dotted line ACE would have been traced: then the shaded area enclosed between these two dotted lines represents the extra amount of heat obtained by keeping the air valve in action throughout the whole time.

Another diagram produced by the pyrometer is shown in Fig. 5. The furnace in one experiment was supplied with its ordinary quantity of fuel, and the full line on the diagram represents that produced by the pyrometer, the air valve being shut the whole of the time. A succeeding experiment was made in which the furnace was supplied with its ordinary quantity of fuel as before, but the air valve was open, when the pyrometer described the dotted line. The horizontal lines in the diagram are reduced from the original curved lines. In this diagram the shaded area between the full and dotted lines represents the extra amount of heat obtained by the action of the air valve.

Numerous experiments have been made with the pyrometer, all of which confirm the view that a proper supply of cold air is attended with considerable increase of temperature, particularly immediately after the furnace is supplied with fuel.

Mr. Johnson showed the pyrometer that had been used in the experiments, with the regulating cylinder at work, and explained their action. He observed that the general fear of proprietors of steam boilers that smoke prevention involved a waste of fuel caused a great impediment to the carrying out of smoke burning; and the present apparatus had been devised to meet this difficulty, since waste of fuel was not a necessary accompaniment of the principle, but simply showed a defect in the mode of carrying it out. The object of the pyrometer was to test more fully the result of the apparatus in economising fuel; and it had been found in all the trials that a large increase in temperature took place immediately after firing, instead of the temperature remaining stationary for some time as in ordinary firing without the regulating apparatus. The alternate experiments of opening and shutting the air valve always showed a rise of temperature after firing whilst the valve was open; which appeared conclusive evidence of improvement in the employment of the fuel, more heat being generated by the consumption of the same fuel, in consequence of its more perfect combustion.

The Chairman said he believed it was generally admitted that the additional supply of air to consume the smoke could be introduced without loss of temperature if properly regulated; but the difficulty was to make the apparatus self-acting, and to ensure it from getting out of order. The object might be effected without apparatus, by sufficient care in firing; but it was impracticable to obtain the constant care requisite on the part of the men. The plan described appeared to be well contrived for the purpose, from its simplicity of construction and working, and the principle of action was certainly a good one; it was similar to that of a plan described at a former meeting by one of their members, in which the air was admitted through a regulating apparatus in the firedoor.

Mr. Johnson observed that the main object he had in view was to obtain a completely self-regulating apparatus that could be fully depended upon, and not liable to injury from neglect on the part of the men. The mode of adjusting the apparatus at starting was by stopping the action of the valve at first, and observing how long the smoke appeared from the chimney after firing in ordinary working; and then setting the valve to shut in the same time, so that the additional air was supplied only during the time wanted, whilst smoke was being produced from the fuel and required consuming.

The Chairman asked how long the apparatus had been in operation, and whether more than one was at present at work.

Mr. Johnson replied that it had been applied at present only to the one boiler at their own works; but it had been working there for twelve months, and had proved so fully satisfactory that they were now extending the adoption.

The Chairman proposed a vote of thanks to Mr. Johnson for his paper, which was passed.

The following Paper, by Mr. Thomas Dunn, of Manchester, was then read :—

DESCRIPTION OF AN IMPROVED CONSTRUCTION OF UPRIGHT STEAM BOILERS.

The early forms of upright boilers, with the chimney placed through the crown of the boiler or in the side near the top, allowed a great portion of the heat to pass into the chimney flues. An attempt was made some years ago to retain this heat, by placing tubes of small diameter in the crown of those boilers; this however caused a liability to the collection of dirt and sediment on the top of the tube plates next the fire, causing them to become burned away, as also the ends of the tubes.

These objections led the writer to endeavour to produce a boiler which should retain the heat without the use of tubes, and should also cause a mixture of the gases for the purpose of burning the smoke. This boiler is shown in Figs. 1 to 4, Plate 125.

Figs. 1 and 2 represent a vertical section and sectional plan of an improved upright boiler with two furnaces A and B, the heat and gases from each furnace rising into the crown of the boiler C, in which they meet and combine, the alternate working of the fires causing the flame from one fire to burn the smoke formed in the other, and vice versâ; the heated current then turns down through the space D, passing again through the water before entering into the chimney flue E. Several of these boilers have been made and tested, and have proved in work very satisfactory. One of them has been at work nine months at the writer's works, which is of the following dimensions:—diameter of outer shell, 4 feet 6 inches; height from ground line to top of crown, 10 feet; diameter of inner firebox, 3 feet 11 inches; width of down draught flue D, 5 inches. The whole of the firebox and boiler is of Staffordshire iron, the outer shell being $\frac{3}{8}$ inch thick, and the inner firebox and flue $\frac{7}{16}$ inch thick. The heating surface measures 145 square feet, and the firegrate is $7\frac{3}{4}$ square feet area. The flat water spaces forming the down draught are 3 inches wide, and stayed with screw stays 5 inches apart, similarly to a locomotive firebox.

The following general results were obtained in a set of experiments made with this boiler, taking the mean of three days' working with each description of coal, the steam pressure being maintained at 65 lbs. per square inch throughout, and the temperature of the feed

water at 62° Fahr.:—5·90 lbs. of water were evaporated per lb. of coal with best Lancashire coal at 10*s.* per ton delivered, burning 16·48 lbs. per square foot of grate per hour; 4·38 lbs. of water were evaporated per lb. of coal with Burgy or the refuse of coal pits at 5*s.* 6*d.* per ton delivered, burning 20·90 lbs. per square foot of grate per hour. The outer shell of the boiler was not clothed, which caused a considerable loss of heat by radiation in the experiments.

After trying several of these boilers, the writer constructed one with a circular down draught flue, as shown in Figs. 3 and 4, for the purpose of saving the expense of stays; this plan did not give quite so much heating surface, but allowed rather more grate area, and the results of this boiler were found very similar to those of the former experiments. The fire in this boiler is not divided, as in Figs. 1 and 2, and the gases are therefore allowed to combine in the firebox FF.

This plan of boiler is well adapted for the interior of buildings, where dust and dirt from ordinary boilers would be an annoyance, as the ashpits are below the surface of the floor, and are made to hold the accumulation of a week's ashes. No external iron chimneys or pipes being required, there is also less risk of accident by fire. The expense is not more than that of the ordinary upright boilers. These boilers have been proved with water pressure to 150 lbs. per square inch.

Mr. Henry Maudslay observed that there had been many attempts at the construction of vertical steam boilers, but great difficulty had been experienced in overcoming the practical objections of confined water spaces, liability to get burnt, or difficulty of repair; he remembered Mr. Joseph Maudslay had tried several kinds of vertical boilers, but had finally abandoned the principle, on account of the difficulties in carrying it out satisfactorily. He enquired what was the main peculiarity in the boiler now described.

Mr. Dunn replied that the principal point was the descending flue inside the boiler, to prevent the great loss of heat that occurred

when the draught simply passed upwards into the chimney; this construction also afforded a convenient and compact arrangement for many situations in shops and other places, by having a descending flue passing below the floor, taking up little room and being more free from causing dust and dirt in the shop.

The Chairman asked how long the experiment continued that had been mentioned in the paper, and whether it had been tried on more than one boiler.

Mr. Dunn replied that the trial was for three successive days, and the coal for getting up steam was included, which made the consumption appear high. There were several boilers made on that plan, but he had not had an opportunity of trying the experiment at present on any other than the one employed regularly at his own works.

Mr. Henry Maudslay said he believed the description of vertical boiler in most general use at present was the one used by Nasmyth with the steam hammer, where the heat passed up a circular centre flue; but in that kind a difficulty was experienced in preventing the water spaces from being choked with deposit, and he feared the same difficulty would be found even to a greater extent in the one described, from the number of stays in the flat spaces.

Mr. Dunn said he had had the boiler nine months at work, and had not yet found any difficulty from accumulation of sediment; and he did not think it would arise with ordinary care in washing out.

Mr. Tosh observed that there would not be any greater difficulty than in locomotive boilers from the water spaces getting choked up; more frequent washing out would certainly be required than in plain open boilers; but he did not consider that a serious objection if an advantage was gained by the form of boiler. He thought the vertical boiler might be a convenient and eligible form for several situations where horizontal boilers were not practicable.

The Chairman remarked that vertical boilers with descending tubes had been made by the late Mr. Gough, and used to a large extent as a compact form of portable boiler; and the reversing of the currents by descending flues might give some advantage in economy of fuel. He thought the experiments on the boiler described showed only a small proportion of water evaporated; and asked what observations had been made of the temperature of the heated current passing off to the chimney.

Mr. Dunn said the temperature of flue had not yet been observed; but in the case of the boiler experimented upon there would be a considerable loss of heat by radiation from the external surface, as it had not been coated, and the exposure would tell more on a boiler of small size.

Mr. R. Roberts observed that a construction of upright boiler was invented by the late Mr. Brunton, which he remembered seeing, and he believed it had worked very well as to economy, and had not met with any serious difficulty except from the deposit of sediment.

Mr. I. Dodds remembered Mr. Brunton's boiler, which worked successfully and was not found to have any defects, except that blow-off cocks were not used at that time, and there was only a small plug, which was not a sufficient provision for the regular and frequent washing out that was requisite for keeping the boiler clean. In vertical boilers there was an inseparable difficulty in repairs owing to the difficulty of access to some parts; but for portability and convenience there might be an advantage in some cases outweighing the disadvantages of construction.

Mr. Dunn said he had prepared a small welded boiler $15\frac{3}{8}$ inches diameter and $\frac{1}{2}$ inch thick, for the purpose of testing to a very high pressure, and proposed trying the experiment by hydraulic pressure on the following morning; the boiler was similar in form to the retort boiler that had been described at a former meeting, and the object he had in view was to make a much higher pressure practicable than was employed at present in steam boilers, by simplifying the construction and reducing the diameter and the consequent total pressure upon the boiler.

The Chairman proposed a vote of thanks to Mr. Dunn for his paper, which was passed.

The Meeting was then adjourned to the following day.

In the evening the Members and their friends were invited to a Conversazione in the rooms of the Mechanics' Institution, at which a large and interesting collection of engineering models, specimens, drawings and photographs was exhibited.

The Adjourned Meeting of the Members was held in the Lecture Theatre of the Mechanics' Institution, David Street, Manchester, on Thursday, June 25th, 1857; Joseph Whitworth, Esq., President, in the Chair.

The following Paper, by the President, was read:—

ON A STANDARD DECIMAL MEASURE OF LENGTH FOR MECHANICAL ENGINEERING WORK, &c.

In the address which I had the honour of delivering before the Members of this Institution at the Glasgow Meeting last year, I briefly alluded to the beneficial results which would follow the application of the decimal system to our weights and measures, referring more particularly to the latter. In compliance with the wish expressed by several members of the Council, I propose in the present paper to bring this important subject more prominently under the notice of the members, confining myself however to its practical bearing on mechanical operations, without discussing different systems of notation, which I leave to other and abler hands.

I have long been convinced that great and rapid progress would be made in many branches of the mechanical arts, if the decimal system of measures could be generally introduced. To state the case

broadly, instead of our engineers and machinists thinking in eighths, sixteenths, and thirty-seconds of an inch, it is desirable that they should think and speak in tenths, hundredths, and thousandths. I can assure those who have been accustomed to the fractional system that the change to the more perfect decimal one is easy of attainment, and, when once made, it will from its usefulness and convenience amply repay any trouble which may have attended its acquirement. In the manufacture of my standard gauges of size, the workmen measure to the 1-20,000th of an inch, and these measures are as familiar and appreciable as those of any larger dimensions. It will therefore be at once conceded that the only scale of measurement which can be used for such small sizes and proportionally small differences must be a decimal one, as any other would be productive of insurmountable difficulty, if not of utter confusion.

When the sizes of the fitting parts of machines are determined by sight from the lines on a scale or a two-foot rule, such nicety of measurement is out of the question; and as long as they are made on that system, the progress of improvement will be retarded. My experience has satisfied me that no system of measurement depending on the power of sight is suitable for obtaining the size of the working parts of machines. Where exact size or good fitting is required, the sense of touch is far more to be depended upon. I make standards of size by a system of measurement depending for its accuracy upon the sense of touch; and use an instrument provided with a mechanical multiplier, by which a space is presented to the eye many thousand times greater in extent than is the case where the distance is directly measured by sight only.

With truth of surface, that never-failing element of success, as the basis of operation, we are enabled to measure with exactitude; and there is no difficulty in making parts of machines to fit one another with any degree of nicety: but, when we wish to express correctly by the common fractional system very minute measurements, our ideas are cramped and hampered by an inconvenient and often confused system of notation. What exact notion can any man have of such a size as "a bare sixteenth" or "a full thirty-second"; and what inconvenient results may ensue from the different notions of different workmen as to the value of these terms. A scale of notation that may have suited the old system of manufacture has been left behind, I am happy to say, as the present age has improved on the past; and our improvement has created a want which necessity urges us to supply without delay. In the production of duplicate parts of

machinery, correct measurement is indispensable to ensure good work: and if, as is the case, we are able to measure with all the accuracy and nicety that can be required, we surely ought at once to adopt a system of notation which will properly represent our measurements.

As an illustration of the importance of very small differences of size, I have brought an internal gauge having a cylindrical aperture ·5770 inch diameter, and two external gauges or solid cylinders, one being ·5769 inch and the other ·5770 inch diameter. The latter is 1-10,000th of an inch larger than the former, and fits tightly in the internal gauge when both are clean and dry; while the smaller ·5769 inch gauge is so loose in it as to appear not to fit at all. These gauges are finished with great care, and are made true after being casehardened. They are so hard that nothing but the diamond will cut them, except the grinding process to which they have been subjected. The effect of applying a drop of fine oil to the surfaces of these gauges is very remarkable. It will be observed that the fit of the larger cylinder becomes more easy, while that of the smaller becomes more tight. These results show the necessity of proper lubrication. In the case of the external gauge ·5770 inch diameter, the external and internal gauges are so near in size that the one does not go through the other when dry, and if pressed in, there would be danger of the surface particles of the one becoming imbedded in or among those of the other, which I have seen happen, and then no amount of force will separate them: but with a small quantity of oil on their surfaces, they move easily and smoothly. In the case of the external gauge ·5769 inch diameter, which is 1-10,000th of an inch smaller in diameter than the internal gauge, a space of half that quantity is left between the surfaces; this becomes filled with the oil, and hence the tighter fitting which is experienced.

It is therefore obvious both to the eye and the touch, that the difference between these two cylinders of 1-10,000th of an inch is an appreciable and important quantity; and what is now required is a method which shall express systematically and without confusion a scale applicable to such minute differences and measurements: it should be based on a uniform principle which will accustom the workman to speak of his measures as aggregates of very small differences; and when a good workman becomes familiar with such sizes as 1-1,000th and 1-10,000th of an inch, he will not rest satisfied until he can work with corresponding accuracy. He will also be able to judge of their effect under different circumstances, and know how

much to allow in the fitting parts of a machine, according to their relative importance and the treatment they are likely to receive at the hands of the attendant. For instance, the cylinder of the moving headstock of a lathe requires as good a fit as possible; but in practice it is found that the cylinder must be ·0005 inch or 1-2000th of an inch too small, because it frequently happens that machinery is not kept in a proper state of cleanliness, or from motives of false economy is lubricated with bad oil. These are two evils which are productive of great mischief. The abrasion caused by accumulated dust and grit produces increased wear and tear, and soon injures the surfaces in contact; while bad oil becomes sticky and rancid, and spoils the working of a good fit.

And here let me state what I think is the proper definition of a good fit. A tight fit is not necessarily a good one; but when the surfaces are true, and a proper allowance is made in the size of the parts working together, then a good fit is obtained. What constitutes a proper allowance or difference in size depends on the nature of the case, and the treatment which the machinery will meet with. In machinery supplied to establishments using rape oil there must be greater allowance and looseness in the fits than would be requisite if better oil, as sperm oil, were used. I need scarcely say how much more advisable it is to have the more accurate fit and use the best oil, than to have a loose fit and use the inferior oil which causing more friction consumes greater power.

Again, a good workman acquires by experience an intuitive knowledge of the allowances in size which are requisite in various cases; and if a suitable decimal system of notation be adopted, there will be no difficulty, with the power of measurement we now possess, in registering minute differences; and so the knowledge gained by the experienced workman may be imparted to others in precise terms, which to the young beginner will be of invaluable service. Much important information may by these means be stored up, and at any time reference can be made to the experience of the past, which will then run no risk of being lost through disuse, inattention, or other causes.

The deterioration of templates or patterns of size, from their becoming worn or altered in process of time, is productive of great inconvenience, as many of us perhaps have experienced. For when an original standard was thus altered, it was irretrievably lost, because there were no means of ascertaining and recording the exact measure. It is of great importance to the manufacturer who makes

parts of machines in large quantities to have the means of referring to an accurate fixed measure: it will enable him to reproduce at any time a facsimile of what he has once made, and so preserve a system of sizes of the fitting parts unaltered. The greatest care should be taken to make standards of size correctly at first, and to preserve them unaltered. Errors in the standards are not only propagated in the copies, but are superadded to the errors in the workmanship, which will occur in the course of manufacture; and this is especially likely to occur in cases where one manufacturer supplies parts of machines for the use of another.

My argument is shortly this:—If we had a better system of notation for our measures, in which small differences in size were expressed in terms conveying their value to the mind, the importance of minute and accurate measurements would become more familiar, more appreciated, and more generally applied. Many operations would by that means be more easily and effectually performed, and in some cases greater safety will be the result. Take for instance the present method of proving guns, which are proved by firing them with a considerable charge of powder and shot. If the barrel stands the proof without manifest injury, it is passed as a good one, while it may in the very process of proof have received such permanent injury as to render it highly dangerous for use. How much better it would be after proving the barrel to measure it, and ascertain accurately if any, and what, permanent alteration had taken place, and retain or reject it accordingly. This would be substituting an exact and satisfactory system for an uncertain and dubious trial; but, inasmuch as the degrees of alteration will be various, and the differences in their measurement very minute, a better system of notation with the improved mode of measuring is required, to enable this and other similarly useful applications to be made.

After careful thought and a comparison of different scales, I have come to the conclusion that the scale for Standards of Size given in the accompanying Table is the one I would recommend to be adopted. I have endeavoured to arrange one which would be easily intelligible to the ordinary workman, and that would in every possible case coincide with the old system, so as not to cause more expense in altering the present sizes than may be absolutely necessary. I am perfectly aware that other scales may be devised more complete and more advantageous in many respects, if we were now prepared not merely to revolutionise but to abandon what has

been manufactured and is now in use. But would not that be going too far? As long as the machines already made are in existence, the sizes of their parts cannot be abandoned; and these considerations have induced me to propose a scale which shall combine the greatest possible advantages with the least possible change.

It would be desirable that those establishments which may decide upon adopting the decimal scale should introduce rules having the inch divided into tenths and their subdivisions, which would soon become as familiar to the workman as the eighth scale he now uses.

The scale proposed for the Wire-Gauge commences with the smallest size and increases by thousandths of an inch up to half an inch. Contrary to the custom usually adopted in marking the wire-gauge, I have called the smallest size No. 1, being 1-1000th of an inch, No. 2 being 2-1000ths of an inch, and so on; increasing up to No. 20 by 1-1000th of an inch between each No.; from No. 20 to No. 40 by 2-1000ths; from No. 40 to No. 100 by 5-1000ths of an inch. I propose therefore to suppress the use of the numbers of designation which have been hitherto employed for the various wire-gauges, and simply call the sizes by their expressive numbers in thousandths of an inch, as shown in the accompanying Table of Wire-Gauges; a change which will, I think, render the new scale easily intelligible and convenient for use.

MR. WHITWORTH'S PROPOSED DECIMAL SCALE.

STANDARDS OF SIZE.

Proposed Standards of Size for Taps and Dies.		
No. of Screw Threads per Inch.	Old Sizes.	New Standards of Size. Decimals of an Inch.
48		·100
40	$\frac{1}{8}$	·125
32		·150
24		·175
24		·200
24		·225
20	$\frac{1}{4}$	·250
20		·275
18		·300
18		·325
18		·350
16	$\frac{3}{8}$	·375
16		·400
14		·425
14		·450
14		·475
12	$\frac{1}{2}$	·500
12		·525
12		·550
12		·575
12		·600
11	$\frac{5}{8}$	·625
11		·650
11		·675
11		·700

WIRE-GAUGE.

Proposed Standard Wire-Gauge.		Old Birmingham Wire-Gauge.	Old Lancashire Wire-Gauge.	Old Metal or Plate-Gauge.	Old Needle Wire-Gauge.	Old Music Wire-Gauge.
Value of each No. in Decimals of an Inch.	New Nos. of Gauge. Thousandths of an Inch.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.
·001	1					
·002	2					
·003	3					
·004	4	36		1	19	
·005	5	35		2	18	
·006	6	...		...	...	
·007	7	34		...	17	
·008	8	33		3	16	
·009	9	32		...	15	
·010	10	31		4	14	
·011	11	...	...	...	...	
·012	12	30	...	5	13	
·013	13	29	80	6	12	
·014	14	28	79	...	11	
·015	15	...	78	7	...	
·016	16	27	77	8	10	
·017	17	...	...	...	...	
·018	18	26	76	...	9	6
·019	19	...	75	9	...	7
·020	20	25	...	...	8	8
·022	22	24	74	...	7	10
·024	24	23	72	10	6	12
·026	26	...	71	...	...	13
·028	28	22	70	11	5	14
·030	30	...	68	...	...	15

10	1	·750	1·125	7	·032	32	45	21	66	...	4	16
10		·800	1·250	14	·034	34	50	...	64	12	...	17
9		·87 5	1·375	14	·036	36	55	20	62	13	3	18
9		·900	1·500	14	·038	38	60	...	61	...	...	19
8		1·000	1·625	13	·040	40	65	19*	59	14	2*	20*
7		1·125	1·750	13	·045	45	70	...	56	15*	1	
7		1·250	1·875	12	·050	50	75	18	55	16		
6		1·375	2·000	12	·055	55	80	...	54	17*		
6		1·500			·060	60	85	17*	52	18		
5		1·625			·065	65	90	16	51	19		
5		1·750			·070	70	95	15*	49	21*		
4		1·875			·075	75	100	...	47	22		
4		2·000			·080	80		14	45	24*		
					·085	85		...	43	...		
4		2·125			·090	90		13	42	...		
4		2·250			·095	95		...	41	25		
4		2·375			·100	100		...	38	26**		
4		2·500			·110	110		12	34	27**		
4		2·625			·120	120		11	31*	28		
3	4	2·750			·135	135		10	29	31*		
3	4	2·875			·150	150		9*	23	31*		
3		3·000			·165	165		8	19	36*		
3	4	3·250			·180	180		7	13			
3	4	3·500			·200	200		6**	5			
3	4	3·750			·220	220		5	2			
2	4	4·000			·240	240		4*	C			
2	4	4·250			·260	260		3	G			
2	4	4·500			·280	280		2**	K			
2	4	4·750			·300	300		1	N*			
2	5	5·000										
2	5	5·250			·325	325		...	I*			
2	5	5·500			·350	350		...	S*			
2	5	5·750			·375	375		00**	V*			
2	6	6·000			·400	400		...	X**			
					·425	425		000				
					·450	450		0000**				
					·475	475						
					·500	500						

NOTE.—These Nos. correspond exactly or within ·001 inch with the new proposed Nos., except those marked * which are within ·002 inch, and those marked ** which are beyond ·002 inch.

The Chairman exhibited a cylindrical gauge of the standard size for the bore of the Government rifles ·5770 inch diameter, and showed that when dry it fitted tight into the internal gauge of the same size, and that another cylinder ·5768 inch diameter or ·0002 inch smaller was quite loose in the same internal gauge, showing that so small a dimension was readily appreciable. On adding a small drop of oil the larger cylinder passed freely through the gauge, but the smaller one fitted tighter than before.

Mr. Dyer enquired what was considered the explanation of the apparently contradictory change produced by the oil in the two cases: he supposed that in the first case the particles in the two pieces of metal being quite clean were in such intimate contact as to bring the actual cohesion of the particles into effect, preventing the motion of one surface over the other; but that when lubricated the minute interstices of the surfaces were filled up level with oil, preventing the particles of metal from coming into such complete contact and allowing the one surface to slide over the other.

The Chairman thought that the action was no doubt of that nature; when the surfaces of the two pieces were quite clean, if the one was forced into the other the surfaces seized and set absolutely fast, but the particles of oil enabled the one piece to make its way into the aperture of the other.

Mr. Fairbairn observed that the question of a decimal system of measure that had been urged in Mr. Whitworth's paper was one of very great importance, affecting all the workshops of the kingdom; and he felt no doubt that if the excellent suggestions of the paper were adopted, it would greatly increase the exactness of work. The accuracy of measurement by the present system was certainly not equal now to the accuracy attainable in workmanship. In steam engine work and particularly locomotive work the true system was for all corresponding parts to be perfect duplicates, and this could be thoroughly carried out only by great certainty and accuracy in measurement. He considered the country was much indebted to Mr. Whitworth for having brought the subject forward in this practical manner, after having afforded them such lasting aid in obtaining accuracy of work. He had no doubt that if a number of employers of mechanics were to start the adoption of the proposed decimal system of measurement, it would be generally carried out, as the advantages were so decided that it only required the first difficulties of actual carrying out to be got over, and the sooner that start was made the better.

Mr. McConnell considered the subject a very important one, and felt quite satisfied of the desirability and importance of carrying it out at once. In the present system of measure the bare 1-16th and full 1-32nd were highly unsatisfactory, and mistakes and expense were caused by their indefiniteness and by the various ways of understanding them. The practice of expressing dimensions in feet, inches, and a variety of fractions, was troublesome and complicated, and he had no hesitation in approving a single decimal system as the best mode of removing the objections; he thought they must undoubtedly take the inch as the unit, and that any other would be impracticable for mechanical work generally. It would of course have been highly desirable if the French decimal measure and our own could be amalgamated, as had been often suggested; but he was satisfied that any attempt to change the English measures entirely by substituting another standard, such as the French metre, would be quite impracticable, and would result merely in postponing the whole question indefinitely. The only course now open was to make the best of the present circumstances, and he quite agreed that the inch was the best standard for the purpose, as the most intimately connected with mechanical work generally, and the only one that would not involve any alteration in the value of the other measures now used. He was quite satisfied that Mr. Whitworth's proposal was the best practical solution of the question, and that a combined movement made by mechanical men would ensure its adoption; he knew of many already who were ready to adopt it, and only required the start to be made.

Sir C. Fox fully agreed with the system proposed in Mr. Whitworth's paper, and was much pleased that the proposal had been made; the general adoption of a decimal system of measure was a great desideratum for all mechanical work, to take the place of the present imperfect and confused system, and he fully agreed with the proposal as the best way of accomplishing the object. He considered the question of the actual unit to be adopted was not practically of so much consequence as might be supposed at first; the great point was to agree upon the unit and then to stick to it. He believed it was totally impracticable in this country to change the inch, that being identified with all mechanical work; and the inch being involved in all the other existing measures was the best to be adopted as the single unit on which to base the decimal system of measure. The comparison with the decimal system of any other country, such as the French metre system, would then become easy, as a single

multiplier would then translate every measure of the one country into the measure of the other. It would then be required to refer to only one figure for the measures of any country; and in the case of the French metre which was so extensively adopted on the Continent, he might mention, as more convenient to remember than the decimal multiplier, that the metre was represented with great accuracy by three ordinary English measures—3 feet, 3 inches, and 3 eighths. Also in calculating the weight of wrought iron, a bar 1 inch square weighed 3·33 lbs. per foot length very nearly; and the sectional area in square inches multiplied by 10 gave the weight in lbs. per yard length. In adopting the decimal system he thought they must be content with the present inch as practically the most convenient unit; dimensions in inches could be readily brought into feet or yards if required, but a foot or yard decimally divided would be impracticable in relation to inches. The present national standard yard would still serve, being considered as 36 inches, and this was already verified by reference to the length of a seconds pendulum expressed in inches; the standard itself, of which he had seen one of the originals at the Royal Astronomical Society, was a gun metal bar about an inch square and a little over 4 feet long, having engraved upon it one yard, and one foot in addition divided into inches. In reference to the French standard, the metre, it was a curious circumstance that, instead of being as was originally intended the 1-10,000th part of one degree of latitude measured at Paris, it was now found to be incorrect to a small extent from the results of more accurate recent measurement.

Mr. McConnell suggested that, after the discussion of the question by the meeting, it was advisable that the present meeting be made a starting point for carrying out the proposed system; and that a first step be taken by passing a resolution expressing their approval of the proposed decimal system of measure, and engaging to unite in bringing it into general use.

Mr. Crampton concurred heartily in this suggestion; he thought the proposed change was very desirable, and the question was one that should be taken up and settled by mechanical men. Mr. Whitworth's proposal was not professed to be absolutely perfect, but he quite agreed that it was the best practical solution of the difficulty. Some little sacrifice and inconvenience was of course inevitable in such a change; but in the proposed system the difficulties were reduced to so small an amount, by taking advantage of so many existing sizes to be retained in the decimal system, that its adoption

when once fairly started would be much easier and simpler to effect than might at first appear probable. He thought the Institution of Mechanical Engineers should form a Committee for the purpose of fully investigating the question and carrying out the application of the system, and that all the Members should do their best to aid in advancing so desirable an object.

Mr. Henry Maudslay considered it very desirable to refer the question to a Committee, that the whole subject might be fully investigated; and thought it would be preferable for this Committee to have the opportunity of considering the subject maturely and collecting information and suggestions as widely as possible, to report to the next Meeting of the Institution, before any resolution was passed upon the subject. He thought the subject was one of great importance to the mechanical world, and they were greatly indebted to the President of the Institution for the consideration he had given to it, and the proposition he had made for carrying it out; the principle of decimal measure was one that he fully agreed with, and it was only in reference to the details and mode of adoption that he thought a longer consideration was advisable before taking any definite step towards carrying it out.

The Chairman observed that the decimal scales he had proposed were really the same as those now existing, both for standards of size and for the wire gauge, excepting a few of the less important sizes, 16ths and 32nds, which he proposed to replace by others agreeing better with a decimal scale; so that in effect the only change proposed was to express all dimensions by a uniform decimal scale of 1000ths of an inch, instead of the present complicated and uncertain system of 8ths, 16ths, and 32nds, and the various wire gauges for smaller dimensions. By this means the exact value of all the present 8ths was retained, on account of the expense and inconvenience that would be involved in abandoning all the present taps and dies, &c., of those sizes, besides the great difficulty and indeed practical impossibility of effecting such a change. This was of course not a perfect system; but he was convinced after several years' consideration of the subject that there was no chance of getting a more perfect one introduced, and any such proposal would simply result in doing nothing. The great object was to get the decimal system of measure recognised and introduced; when once got into general use its advantages would naturally lead to further simplifying the scale and gradually dropping the more complicated decimals.

The proposed decimal wire gauge was a more perfect proposition, as the case was a much simpler one; all the existing sizes of the various gauges could be represented by a scale of 1000ths of an inch, and it was therefore proposed simply to call each size by its real value in 1000ths of an inch. For example, the present No. 16 wire gauge gave no idea by its name of the actual dimension spoken of; but the name proposed to be substituted, No. 65, showed at once it was 65-1000ths of an inch, or 6½-100ths: and the two tables being both expressed in 1000ths of an inch, the wire gauge became at once a part of the same series of dimensions as the standards of size for taps, &c., instead of being an entirely unconnected and incommensurable scale. In the proposed scale most of the present sizes were exactly retained, some others being slightly altered in amount to bring them into a more regular progression of sizes than the present scale, which had irregular intervals at some parts. The want of a definite value expressed by each size of the wire gauge led to an extensive and serious evil, for the gauges in use varied materially both in original construction and also from the unavoidable effects of wear; there was thus no definite standard of appeal, so that serious difficulties arose in manufactures from the discrepancies between the gauges used by different parties; and the uncertainty was so great that in the smaller sizes it was customary to send patterns of the thickness required, instead of trusting to the No. of the gauge.

Mr. Dyer considered the question of a decimal system of measure a very important one, and one very desirable to be settled and carried into effect at once; he thought this would be best done by mechanical men undertaking to work it out, and they could not have a more appropriate opportunity for starting it than the present meeting in Manchester of the Institution of Mechanical Engineers. The advantages of a uniform system of decimal measurement would be very great throughout all their mechanical works and manufactures. As to the standard to be adopted, it did not appear to him at all a serious objection that different nations could not agree to adopt the same standard; the English standard and the French metre were both already in extensive use throughout the world, and might so continue, and the comparison between the two sets of dimensions would be readily made when both were decimally divided; it should be also observed that both standards were in fact of an arbitrary nature, being metallic rods carefully preserved for reference in government offices, and each of them legal measures without reference to the supposed natural relation of the French metre to an arc of the meridian.

Sir C. Fox thought it was important that the opportunity of that meeting should be taken to agree upon a resolution as a first step towards carrying out the desired object, the members and visitors present pledging themselves to the adoption of a decimal system of measure, and fixing upon the inch as the unit of measure to be divided decimally into 1000 parts.

Mr. McConnell cordially supported the proposal; he was quite ready to adopt the decimal system proposed by the President, and thought the present meeting was certainly the right occasion for taking the first step towards carrying it out.

Mr. Fairbairn thought the proposal should be adopted at once, and considered it the best step that could be taken to advance the object.

Colonel Kennedy had long thought the subject a very desirable one to be carried out, and was much pleased that it had been now taken up by the Institution of Mechanical Engineers; he considered that was the most effective way of obtaining a definite practical result, and hoped the present meeting would decide upon the adoption of the decimal system of measure, and provide for working it out at once by means of a Committee.

Mr. Clift was confident that the advantages of the proposed decimal system would be found so great, that it was only necessary to make a start and to have rules made divided decimally, in order to get the system at once introduced into workshops; he had no doubt that its adoption would be found less difficult to effect than might at first seem probable.

Mr. Aston thought it was decidedly the best course on the present occasion to determine on the adoption of the general principle of decimal measure founded on the inch as the unit, as it was clear that that course would completely answer the present purpose, and admit of the system being carried into practice, when the details had been further worked out by a Committee.

Professor Rankine fully agreed in the proposal; he considered it would be a very useful and desirable change to drop the present fractional measures in all mechanical work, and he was ready to adopt the decimal system at once in figuring mechanical drawings, where the use of ordinary fractions was undoubtedly inconvenient and more liable to cause errors.

Mr. I. Dodds had long felt the great inconvenience of the common fractional dimensions; the bare and full 16ths were very objectionable and imperfect, though used so frequently in mechanical work; and

there would be undoubtedly an important advantage in accuracy and convenience from the adoption of the proposed decimal system of measure.

The following resolution was then passed :—"That this meeting pledge themselves to the adoption of the decimal scale, the inch being divided into 1000 parts."

The following Paper, by Mr. Charles Fay, of Manchester, was then read :—

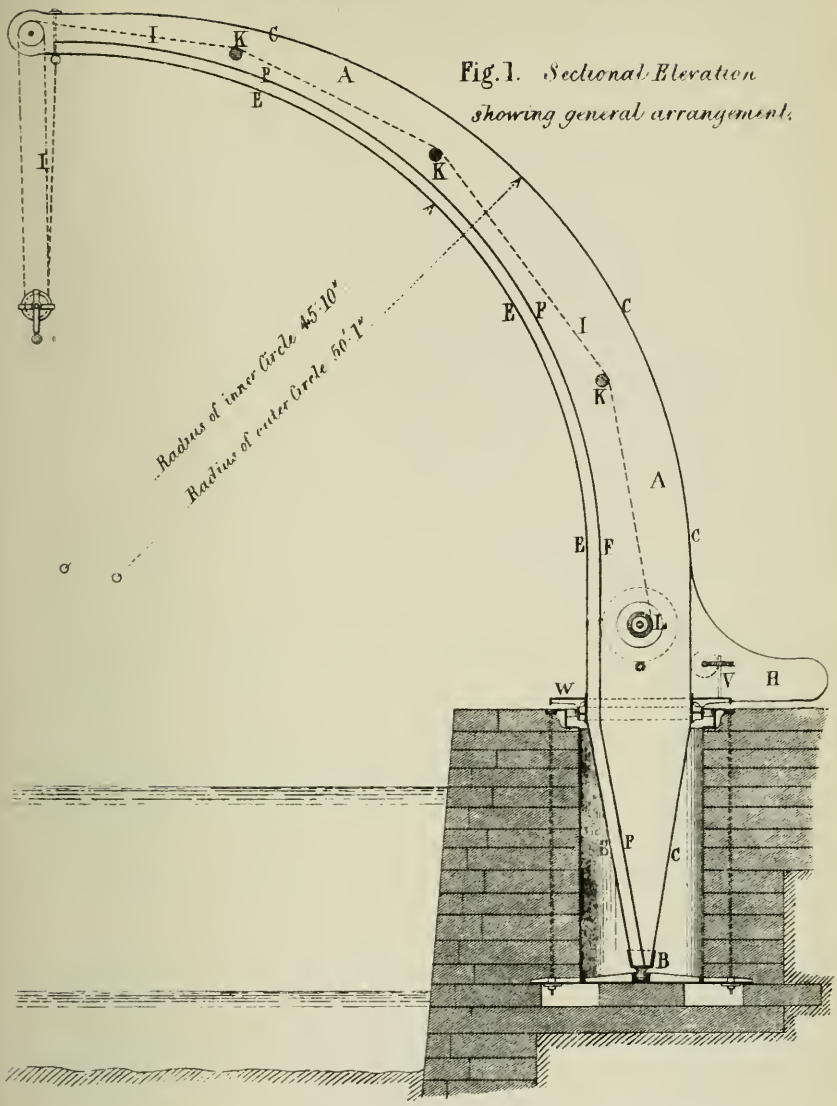
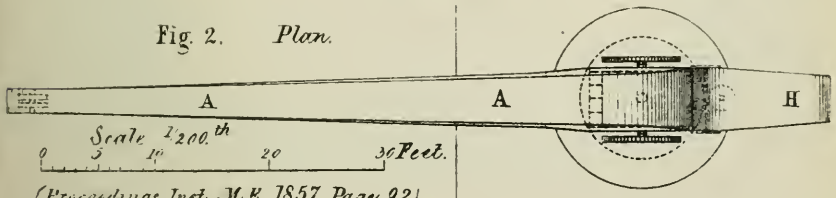


Fig. 1. *Sectional Elevation showing general arrangement.*

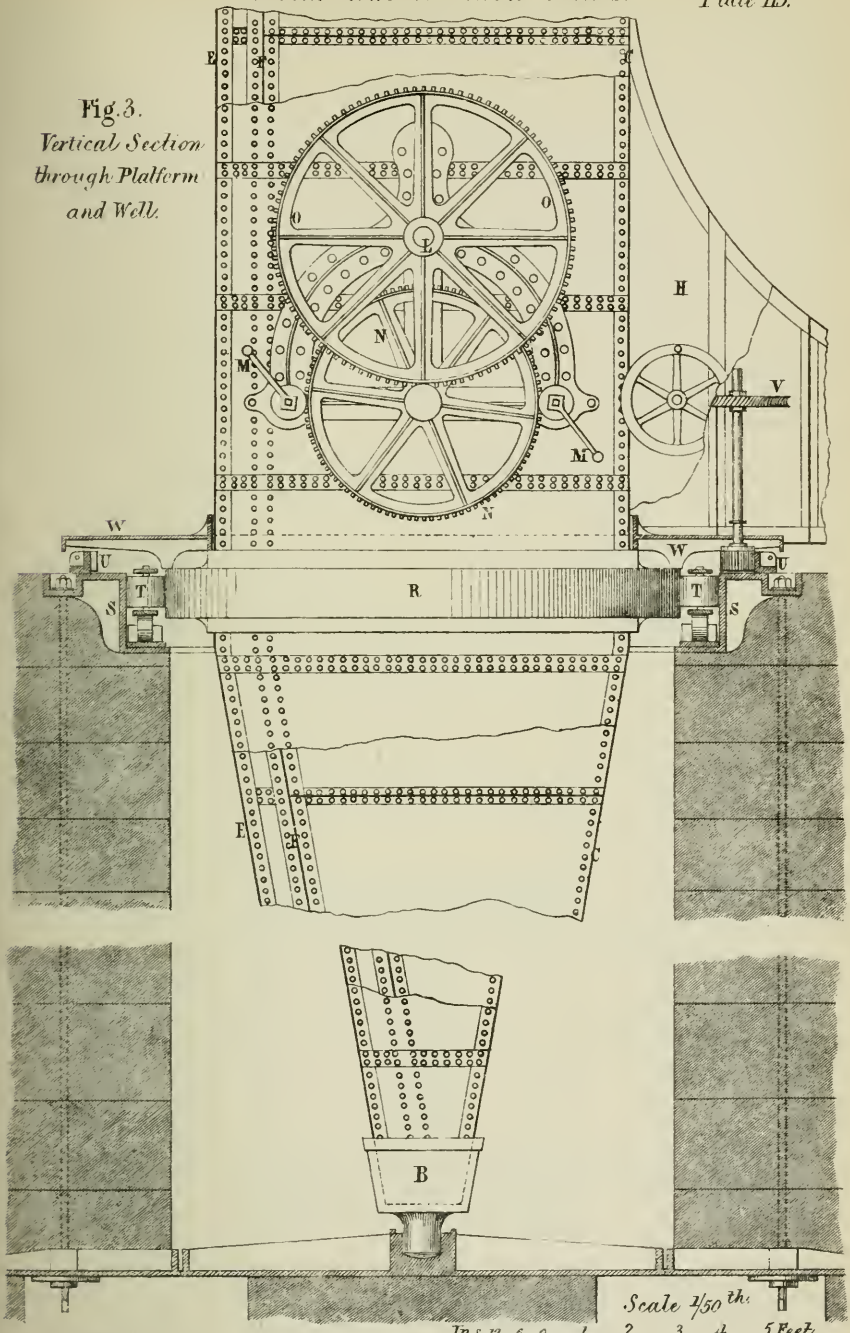
Fig. 2. *Plan.*



(Proceedings Inst. M.E. 1857. Page 92).

TUBULAR WROUGHT IRON CRANE. *Plate 115.*

Fig. 3.
Vertical Section through Platform and Well.



(Proceedings Inst. M.E. 1857 Page 92).

Fig. 4. *Plan at Roller Path.*

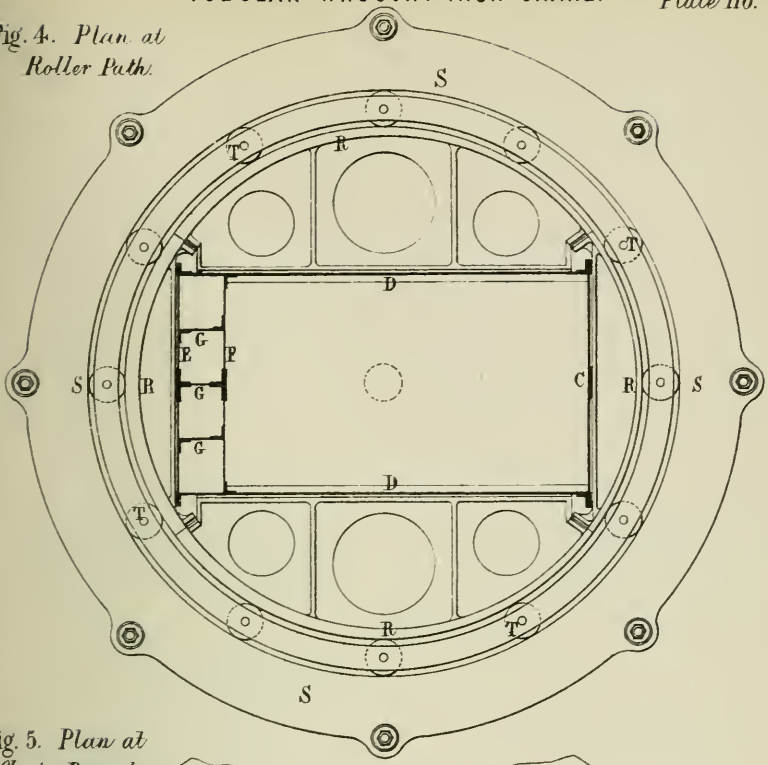
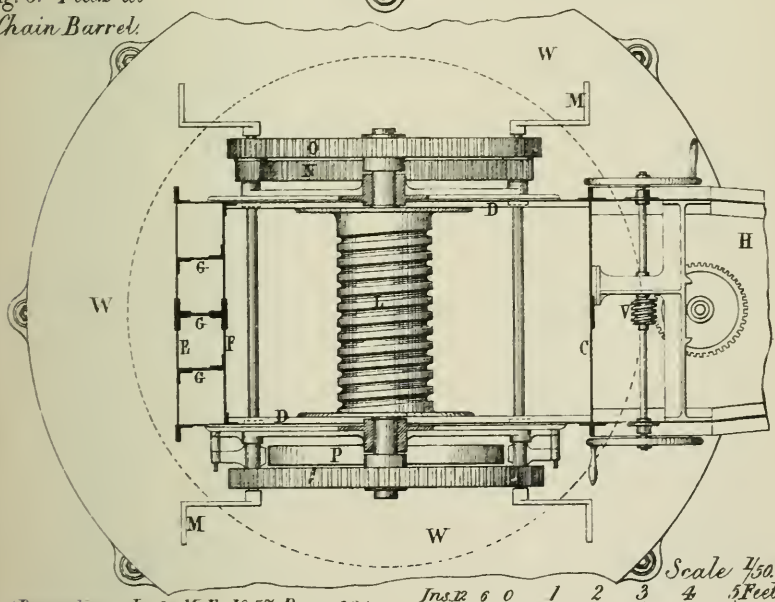


Fig. 5. *Plan at Chain Barrel.*



Scale 1/50th.

Ins. 12 6 0 1 2 3 4 5 Feet.

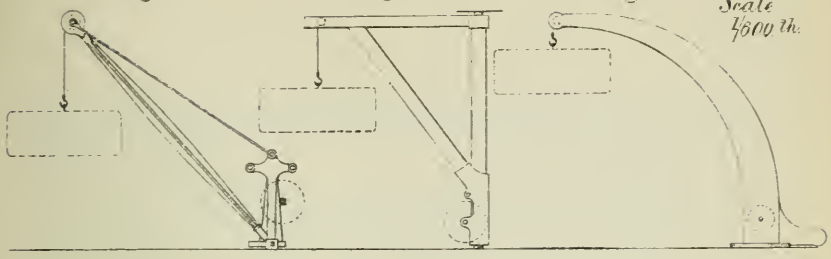
(Proceedings Inst. M.E. 1857. Page 92.)

TUBULAR WROUGHT IRON CRANE.

Plate 117.

Fig. 6. Fig. 7. Fig. 8.

Scale 1/600 th.



FEED PIPE CONNEXION.

Fig. 1. *Longitudinal Section.*

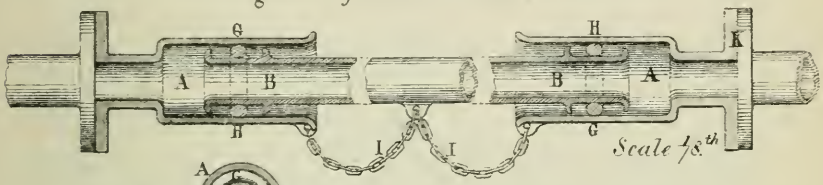


Fig. 2. *Section at GH.*

EVAPORATING POWER OF TUBES.

Experimental Boiler.

Fig. 4. *Vertical Section.*

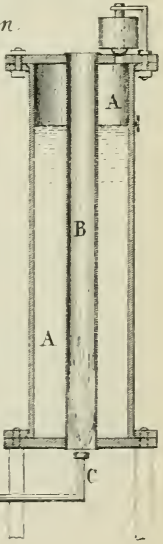
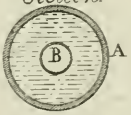


Fig. 5. *Transverse Section.*



Scale 1/12th.

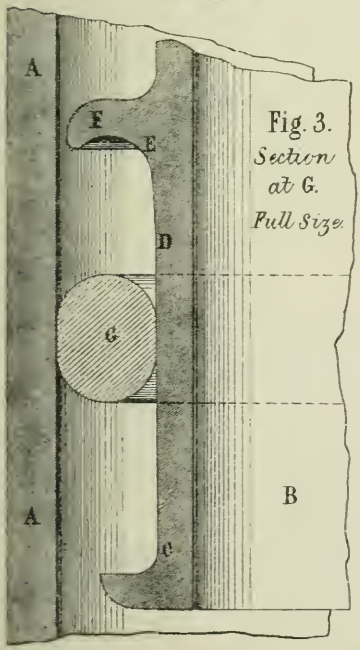


Fig. 3. *Section at G. Full Size.*

(Proceedings Inst. M. E. 1857. Page 88.)

REGENERATIVE FURNACE.

Plate 118.

Fig.1. *Longitudinal Section.*

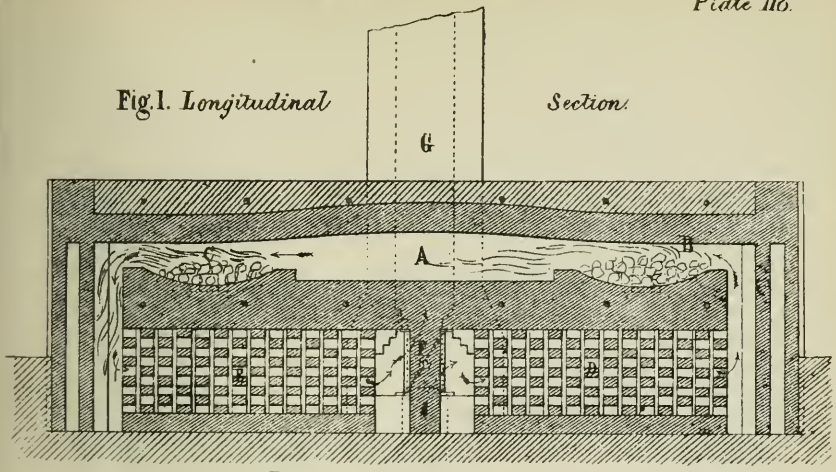


Fig.2. *Sectional Plan.*

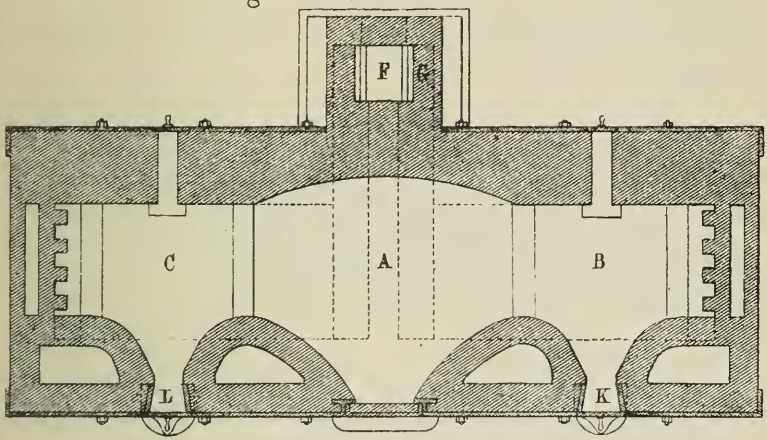


Fig.3. *Transverse Section through Heated Chamber.*

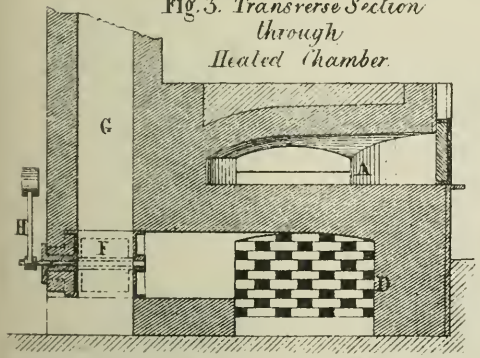
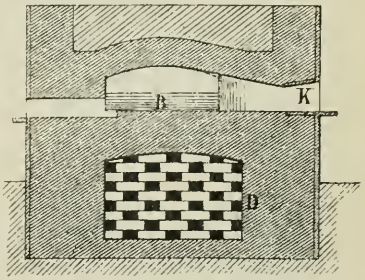


Fig.4. *Transverse Section through Fireplace and Regenerator.*



Scale 1/100th Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

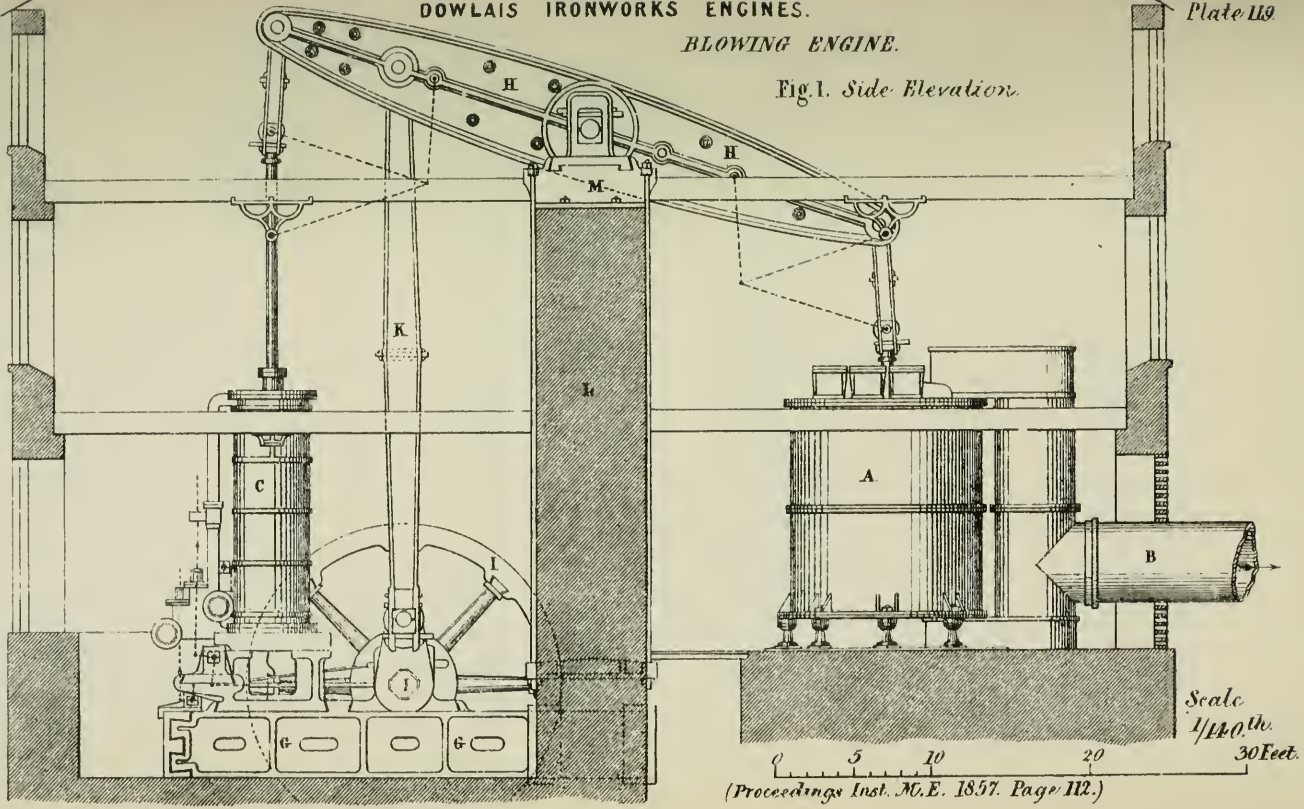
(*Proceedings Inst. M. E. 1857. Page 104.*)

DOWLAIS IRONWORKS ENGINES.

Plate 119

BLOWING ENGINE.

Fig. 1. *Side Elevation.*



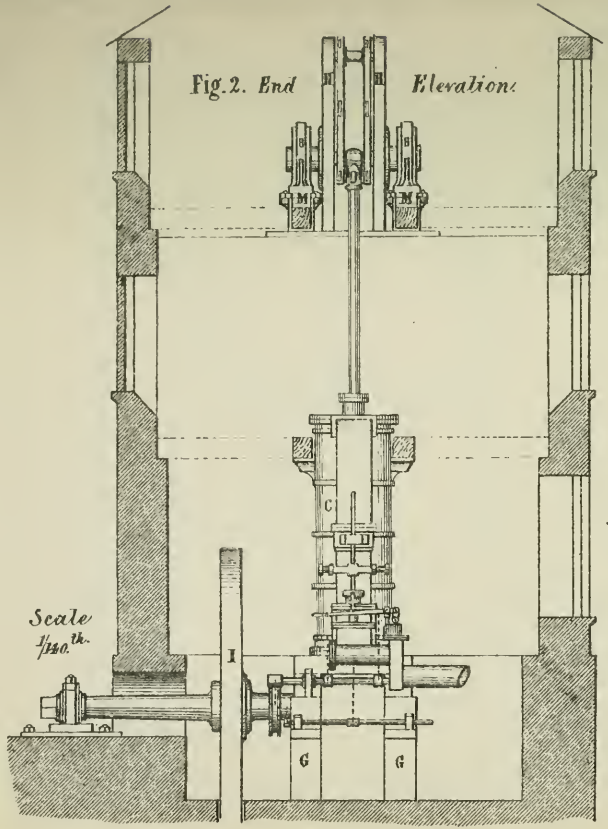
(*Proceedings Inst. M.E. 1857. Page 112.*)

DOWLAIS IRONWORKS ENGINES.

BLOWING ENGINE.

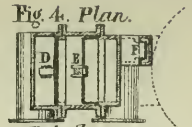
Plate 120.

Fig. 2. *End Elevation.*



Scale 1/20th.

Fig. 4. *Plan.*



Detail of Steam Valves.

Scale 1/10th.

Fig. 5. *Vertical Section.*

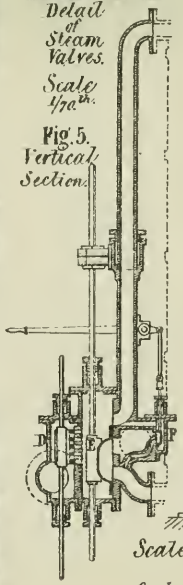
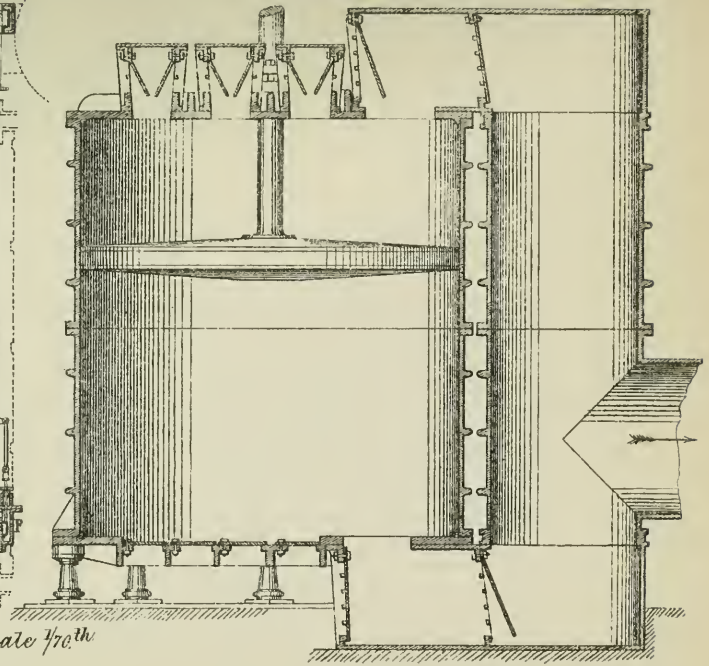


Fig. 3. *Vertical Section of Blowing Cylinder.*



Scale 1/70th

0 1 2 3 4 5 6 7 8 9 10 20 Feet

(Proceedings Inst. M.E. 1857. Page 112.)

DOWLAIS IRONWORKS ENGINES.

ROLLING MILL ENGINES.

Plate 121

Fig. 6. *Side Elevation.*

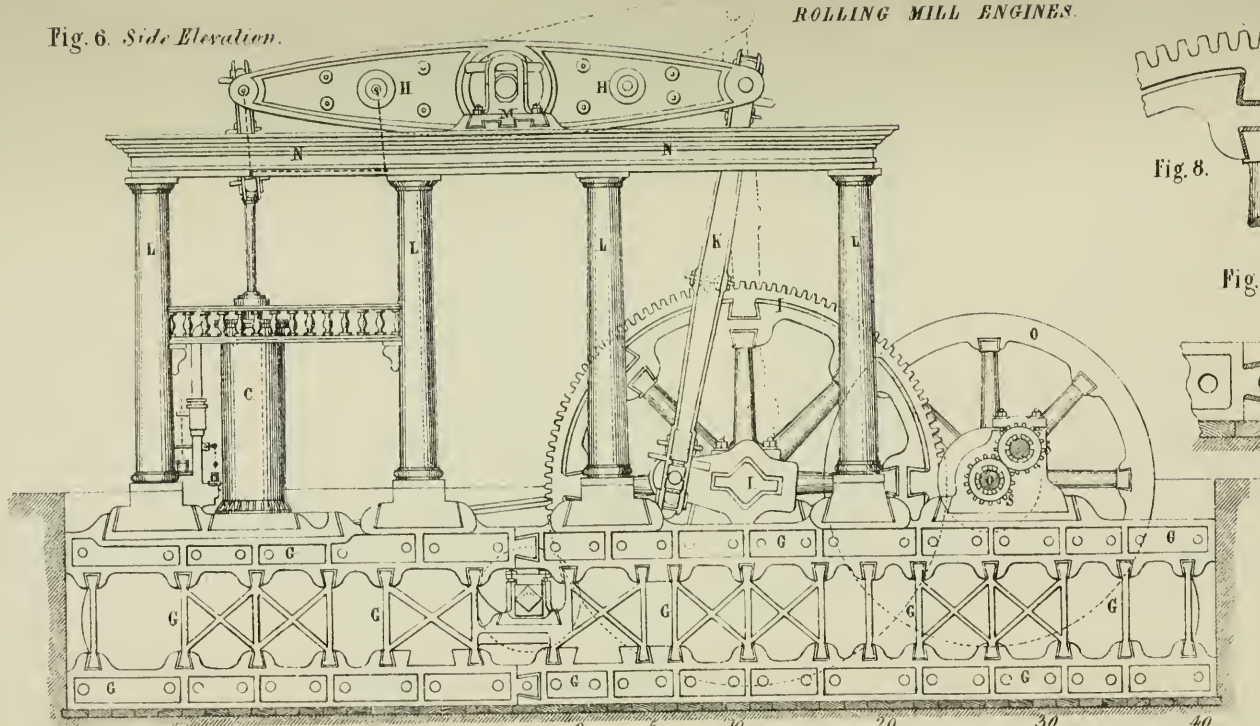


Fig. 8.

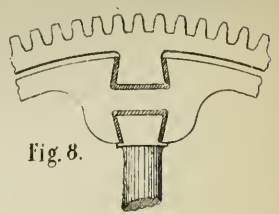


Fig. 9.

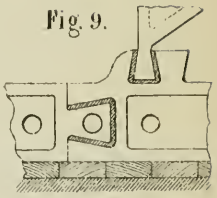
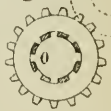


Fig. 10.



Scale 4/70th

(*Proceedings Inst. M.E. 1857. Page 113.*) Scale 1/140th

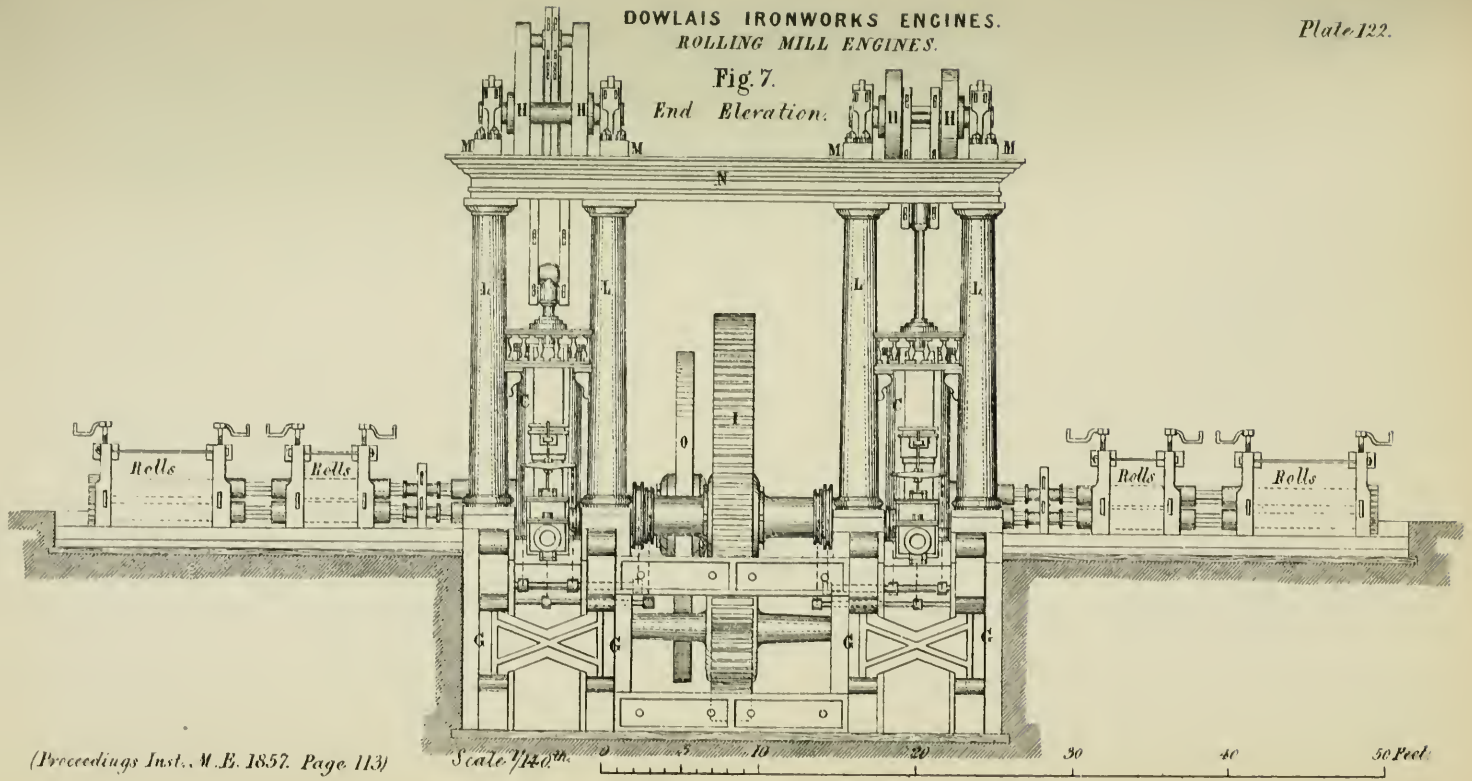
DOWLAIS IRONWORKS ENGINES.

ROLLING MILL ENGINES.

Plate 122.

Fig. 7.

End Elevation.



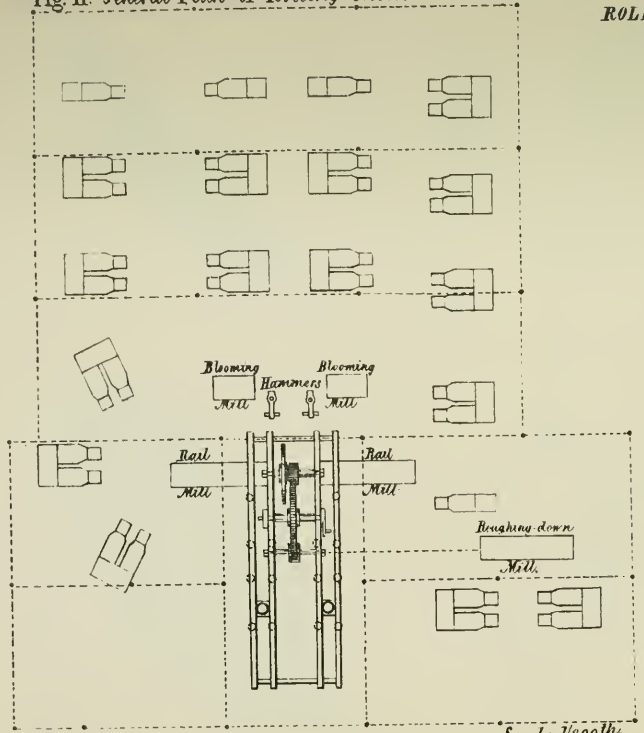
Scale 1/40th. 0 5 10 20 30 40 50 Feet.

(Proceedings Inst. M.E. 1857. Page 113)

DOWLAIS IRONWORKS ENGINES.

ROLLING MILL.

Fig. 11. *General Plan of Rolling Mill.*



(Proceedings Inst. M.E. 1857. Page 113.)

Scale 1/800th.

Fig. 12. *Front Elevation.*

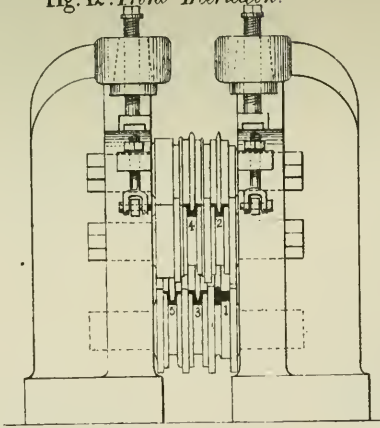
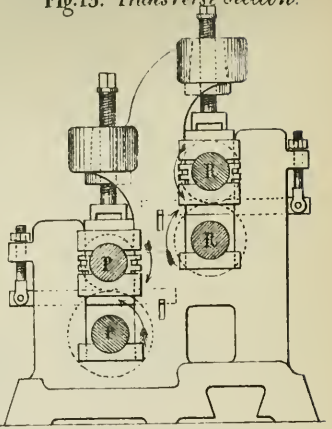
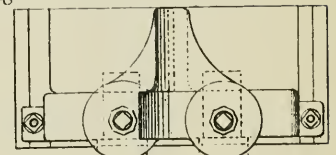


Fig. 13. *Transverse Section.*



Arrangement of Rolls for rolling in two directions.

Fig. 14. *Plan of Standard.*



Scale 1/50th

Inches 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet.

Fig. 1. *Longitudinal Section of Boiler.*

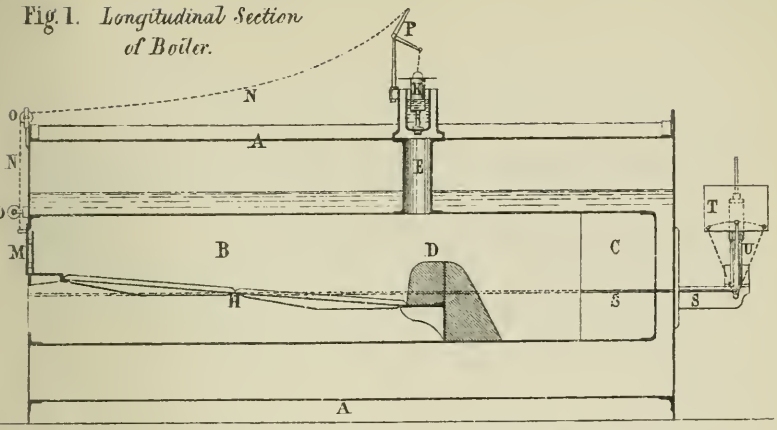


Fig. 2. *Transverse Section of Boiler.*

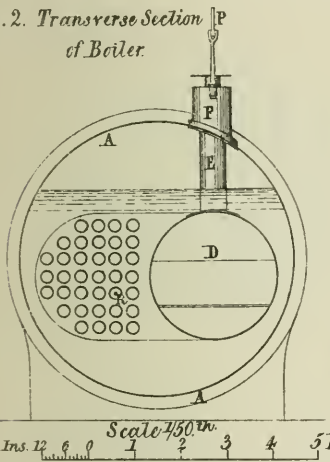
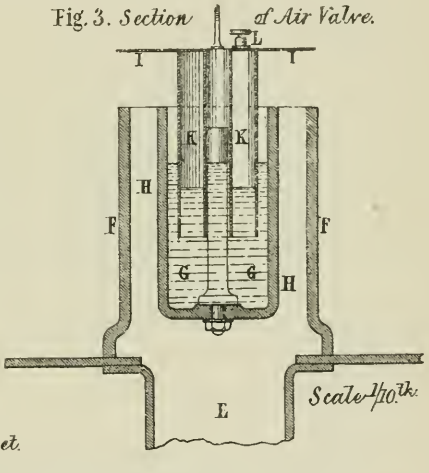


Fig. 3. *Section of Air Valve.*



Pyrometer Diagrams.

Fig. 4.

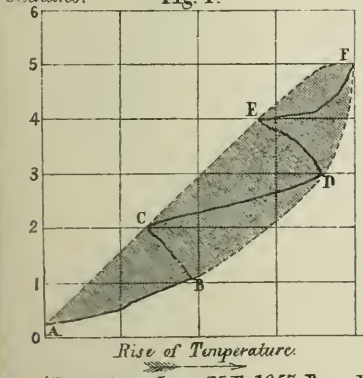
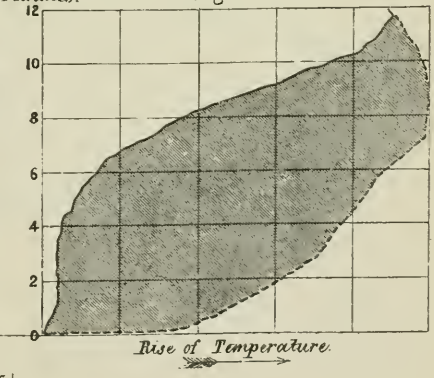


Fig. 5.



(*Proceedings Inst. M.E. 1857. Page 125.*)

UPRIGHT STEAM BOILER.

Plate 125.

Fig. 1.
Vertical Section.

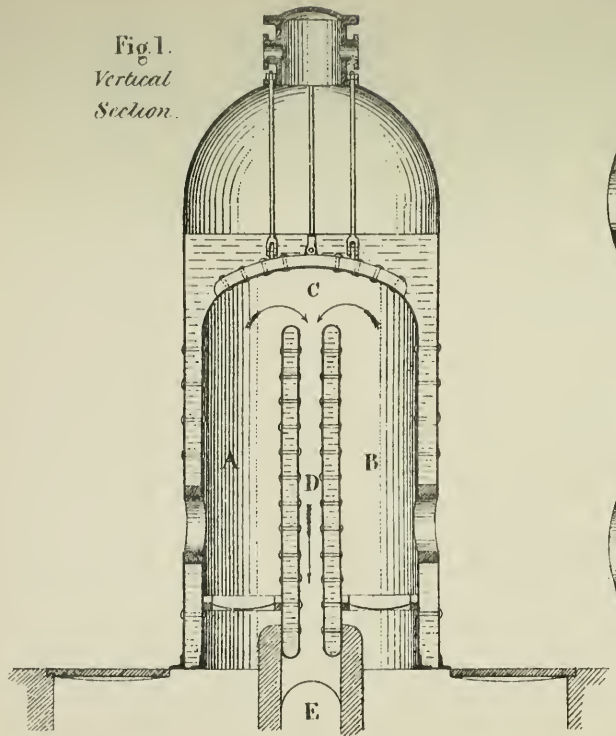


Fig. 2. *Sectional Plan.*

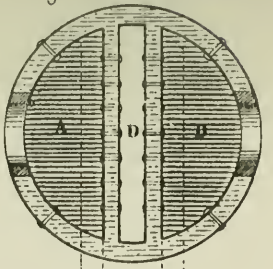


Fig. 4. *Sectional Plan.*

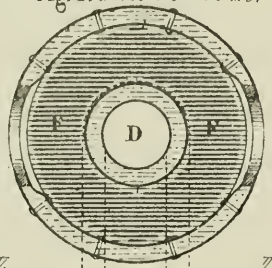
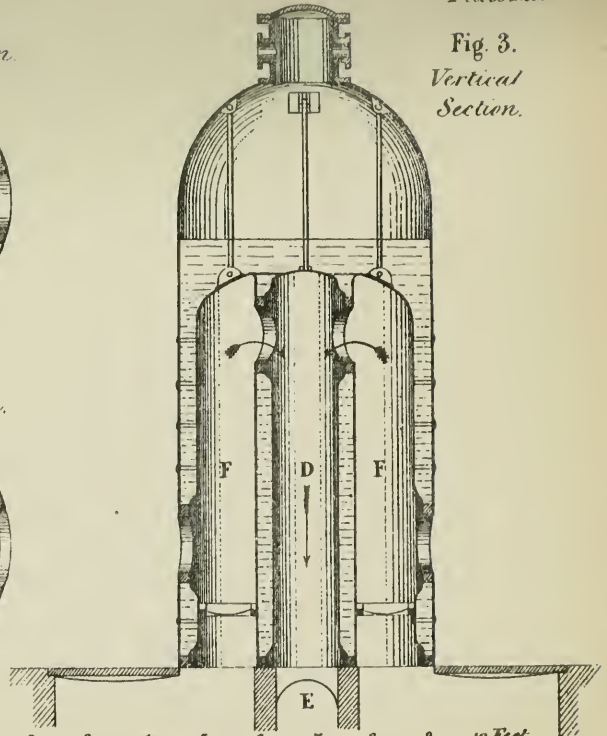
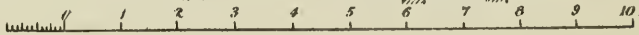


Fig. 3.
Vertical Section.



(Proceedings Inst. M.E. 1857. Page 130)

Scale 1/40th.



ON THE SAVING OF DEAD WEIGHT IN PASSENGER TRAINS.

The question has often arisen, though not satisfactorily answered, —Why should it take more dead weight to carry a passenger by railway than formerly by a stage coach? The two modes of transit scarcely admit of a fair comparison, as a stage coach runs singly and at a slow speed, and only one fourth of the passengers are carried inside, the other three fourths being outside; and when required to be brought to a stand, it is done without any violent or sudden shock or strain on the vehicle: whereas on a railway a large number of carriages are coupled together, the train travels at a high speed, and is often suddenly checked and shunted with great force into a siding, coming into contact with heavy wagons without buffer springs; the carriages have therefore to be built sufficiently strong to withstand the strains and shocks to which they are subjected. Although it is not a practical comparison, as passengers cannot be carried outside on railway carriages, yet if the mode of carrying passengers by stage coach be applied to railways, the following will be the results:—an ordinary four-horse stage coach, seating 4 inside and 12 outside, or a total of 16 passengers, and weighing about 20 cwt., gives an average of 140 lbs. of dead weight to each passenger; now if this be compared with one of the large third class carriages built by the writer for the Lancashire and Yorkshire Railway, and now running on the Oldham branch, which are 28 feet long, 8 feet 6 inches wide, seating 84 passengers, and weighing 6 tons 11½ cwt., then, supposing passengers were carried on the roof in addition, as on a stage coach, it would seat about 84 more, allowing 16 inches for each passenger, or a total of 168 passengers, which gives an average of only 88 lbs. of dead weight per passenger as compared with 140 lbs., or a difference in favour of the railway over stage coaches of 52 lbs. of dead weight per passenger. But although it is unreasonable to expect passengers to be carried on railways all inside with only the same amount of dead weight as by stage coach, where three fourths are carried outside, it certainly cannot be thought unreasonable to ask whether passengers cannot be carried by railway with less dead weight than at present; this the writer considers practicable, and further that every pound of unnecessary dead

weight added to any part of a vehicle does not add to its strength but diminishes it, for being out of proportion to the other parts it is rigid and does not yield uniformly to the strain.

In the writer's opinion, the correct means of saving dead weight is in building the carriages larger, and doing away with unnecessary wheels, axles, axle boxes, springs, &c. For instance, taking an ordinary third class carriage, seating 40 passengers, allowing to each 16 inches of seat room, and weighing 5 tons when empty, this gives 280 lbs. of dead weight per passenger; now the carriage previously named, running on the Oldham branch, weighing 6 tons 11½ cwt., seating 84 passengers, gives 175 lbs. of dead weight per passenger, or a difference of 105 lbs. per passenger in favour of the large carriage. Again, an ordinary modern first class carriage of three compartments, seating 18 passengers, and weighing 5¾ tons, gives a dead weight of 715 lbs. per passenger; whilst one of the larger sized first class carriages used on the Lancashire and Yorkshire Railway, 24 feet long, 7 feet 6 inches wide, allowing the same room and accommodation as the three-compartment carriage, weighing 6¼ tons, and seating 24 passengers, gives a dead weight of 583 lbs. per passenger, showing a saving of 132 lbs. per passenger in favour of the long carriage. But if the comparison is made with a first-class carriage similar to what is running on the Oldham branch, which is 28 feet long, 8 feet 6 inches wide, and 6 feet high in the clear of the doorway, with five compartments, weighing 7 tons 3 cwt., and seating 40 passengers, this gives a dead weight of only 400 lbs. per passenger. This carriage has the seats divided for four passengers, which, although not so comfortable for long journeys as three divisions, is found sufficient for the greater portion of the traffic on most lines.

The writer has lately constructed two carriages to work the Ashton branch of the Lancashire and Yorkshire Railway, shown in Fig. 2, Plate 126, seating 24 first and 120 second and third class passengers, with ample accommodation for guard and luggage. These two carriages with breaks, weighing 16 tons, give better accommodation than the old train, shown in Fig. 1, consisting of six separate carriages, seating 149 passengers, and weighing 30 tons; thereby effecting not only a saving of nearly 14 tons of dead weight per train, but a proportionate saving in first cost nearly equal in amount to the difference in the weight, and also a proportionate saving in wear and tear, both

of engines, carriages, and permanent way, and a saving in consumption of coke of 5 lbs. per mile; there is also found to be a saving in time on the journey, as the guard at every station, when going from one end of the train to the other and back, has to walk a distance of only 50 yards with the new train, instead of 88 yards with the old train.

The writer is of opinion that large carriages are very suitable for main lines, but more particularly so for branch lines, and have many advantages over small ones, not only in dead weight and cost of construction and working, but in having a smaller number of carriage ends; for most passengers, particularly first class, prefer middle compartments, and the old Ashton train, shown in Fig. 1, has 12 carriage ends, whereas the new one has only 4. Another advantage is that should any axle break under a short carriage, the chances are it is thrown on its side or turned over; whereas with long carriages in such an accident the carriage is most likely to run as a sledge. A case of this kind occurred on the Lancashire and Yorkshire Railway near Rochdale about three years ago, when during the great snow storm a train that met with an accident had one of these large carriages attached; the front axle had been broken by the collision at the back of the nave, and the hind wheels were swept entirely away, but the carriage was trailed in this way like a sledge for upwards of a mile, and when the train was brought to a stand it continued parallel to the line of rails. Another advantage of the long carriages is that they run not only freely round the curves, but on straight parts of the line with less lateral motion, and the writer has found the brasses in the axle boxes to wear much less endways than in short carriages. The two carriages before named are 33 feet long, with the wheels 18 feet distance of centres; they have been run backwards and forwards with the greatest ease through a curve of less than 200 feet radius, although six-wheeled engines all coupled cannot pass through; and they run many times daily through a curve at Manchester Station of 330 feet radius, and the flanges of the tyres do not show any perceptible wear different from that of any ordinary vehicle.

In reference to increase of size of vehicles, it may be remarked by way of illustration that formerly a 500 ton merchant ship was considered a large size, but now nearly as many thousand tons is not uncommon; for as the commerce of the country has increased, instead of building numerous small vessels, the shipwrights have so increased

the size of the ships that one will now take as much merchandise as several formerly did, thereby effecting a very great saving. But in the case of railways, as their traffic has increased have they taken the same view as ship builders and increased the size of their vehicles to suit their increased traffic? Not generally, only in some few instances; but they have increased the number of their vehicles and made their locomotives heavier and more powerful to draw the increased weight of carriages, and then as a consequence have had to build their carriages stronger to resist the strain of a longer and heavier train and a more powerful engine, thereby increasing the dead weight in a greater ratio than the increased weight of passengers carried. It may be considered an objection to long carriages that, when a train is made up, if there should be a few extra passengers one of these large carriages would have to be attached; but as mixed trains are now generally run, if the carriages were nearly all composite such a case would seldom if ever occur.

Carrying luggage on the roof the writer considers a very objectionable plan, and can only account for it being continued under the impression that it is the most economical: this however he considers not to be the case; for although a carriage roof cannot be built much lighter when luggage is not carried on it, as it must be made strong enough to bear the weight of a man walking along the top to get at the roof lamps, yet in case of accident a great weight on the roof must act at a serious leverage to damage the carriage, or if travelling at a high speed to impart to it a rolling and pitching motion. Many sources of inconvenience to the passengers arise from this plan, such as the difficulty and delay of finding particular luggage at intermediate stations, the annoyance of moving heavy weights over head, and risk of damage from wet; there is also the risk of accident to the men from breaking of the luggage straps in buckling them up, the men having sometimes to strap down the luggage while the train is in motion: these sources of annoyance, inconvenience and trouble to passengers and to the railway servants are much greater than would be supposed at first. Then the first cost is considerable on lines where much luggage is carried, as nearly every carriage has to be furnished with sheets and straps, though perhaps one third of them are not used, and the roofs are much impaired by screwing on the numerous laths to protect the roof covering from being cut by the luggage; the cost of keeping up the luggage sheets and

straps amounts on a large line to a very great annual sum, caused not only by wear and tear, but by those not regularly used deteriorating much more by lying folded up, as they are liable to mildew and rot and to being burnt by hot cinders falling on them.

On some lines the luggage is carried to some extent in vans; but although where this can be done it is much preferable to carrying it on the roof, still it has many objections: the van is generally placed in front or at the end of a train or sometimes at both, and every time the train stops, more especially at a junction, the passengers have either to get out and look after their luggage or run the risk of its not being forthcoming at the journey's end; and at the end, owing to the luggage being all taken out of one place, much inconvenience is caused to the passengers. Where the train has to be broken up this plan cannot be carried out, as a separate van would have to be run with each portion of the train thus separated; so that even when a van is used the luggage has to a certain extent to be carried on the roof. Some lines have luggage compartments in the centre of the carriage, but this arrangement the writer thinks not the most judicious plan, as it is placing the luggage in the best part of the carriage; and he suggests that luggage vans be entirely dispensed with, and that in place of them every carriage be built with a luggage compartment at each end. He is quite convinced that a first class carriage with three compartments and a luggage compartment at each end, say having a total length of 23 feet and seating 18 passengers, and not exceeding 6 tons weight when empty, could be built at very little additional cost to the present carriages; it would be stronger and more able to withstand a strain than a similar carriage of the same weight with luggage on the roof; and if the carriage be longer, say 29 feet and seating 24 passengers, and if wider seating 32 passengers, the difference will be still greater in favour of carriages with luggage compartments. The ends could also be fitted with folding seats to be available for passengers in busy times, seating 10 additional second or third class passengers. The double ends in case of collision would also serve as additional protection to the passengers, the luggage in them acting as extra buffers.

The writer is now building a similar carriage to the last described for the Lancashire and Yorkshire Railway Company, as shown in Fig. 3. It is 29 feet long, seating 24 passengers, and precisely similar in every other respect to the best modern three-compartment carriages;

it will weigh about $6\frac{3}{4}$ tons, giving 630 lbs. of dead weight per passenger, instead of 715 lbs., thereby effecting a saving of 85 lbs. of dead weight per passenger in comparison with the ordinary carriage constructed to carry luggage on the roof. If the carriage be made wider, seating four on each seat, the difference will be still greater. The additional cost of maintaining this extra length will be very trifling; and a saving is effected in first cost equal in proportion to the saving in weight, in addition to the saving in wear and tear of sheets, straps, and roofs of carriages.

Taking another view of the case, suppose a train constructed to carry luggage on the roof to consist of eight ordinary three-compartment first class carriages and a luggage van, each weighing $5\frac{3}{4}$ tons when empty; this train would cost about £2600, seating 144 passengers, with a total dead weight of $51\frac{3}{4}$ tons. A train of similar carriages, omitting the van, but with luggage compartments at each end, each carriage weighing 6 tons when empty, and allowing $\frac{1}{2}$ ton more for the additional size of the carriage with the guard's compartment, would give a total of $48\frac{1}{2}$ tons, or a saving of $3\frac{1}{4}$ tons in favour of the carriages with luggage compartments. But if the comparison is made with a train of six carriages similar to the one shown in Fig. 3, this train would cost about £2100, seating 144 passengers, each carriage weighing $6\frac{1}{2}$ tons when empty, and allowing as before $\frac{1}{2}$ ton more for the additional size of carriage with guard's compartment, making a total of $39\frac{1}{2}$ tons; this gives a saving of $12\frac{1}{4}$ tons of dead weight, and of £500 in first cost, besides the annual saving in wear and tear of sheets and straps, and in busy times the advantage of seating 55 additional second or third class passengers in the luggage compartments.

To prevent the hogging effect of the spring tension bars upon the frame of the carriage, which is subjected to a more severe strain in the long carriages, the writer has adopted a plan which has been found to remove all objections, and at the same time to strengthen the carriage considerably, by trussing the carriage from the end bars of the under-framing to the ends of the axle guards, as shown in Fig. 4. The wrought iron strut A, $1\frac{1}{2}$ inch diameter in the middle and tapering to $1\frac{1}{4}$ inch at the ends, is secured to the end bar B by a flat end and heel bolted to the bar, and the other end of the strut is secured to the axle guard at C with a double shoulder to take the strain off the bolts. A similar strut D, made stronger in the middle, extends from one axle guard to

the other; and in carriages with long centres these middle struts are made of hollow piping to save weight, and are not only tied across to each other, but also to the underframe, and in very long centres diagonal stays are added. The bar E is formed with double shoulders and bolted to the ends of the axle guards to connect the struts.

The axle guards, instead of being made $\frac{3}{4}$ inch thick as usual with the edge working in a groove of the axle box, which is liable to be worn in from $\frac{1}{8}$ to $\frac{3}{8}$ inch after several years' work, have a piece of angle iron rivetted to the legs of the guards, as shown in Figs. 5 and 6, by means of which a face of $2\frac{3}{4}$ inches wide is obtained to work against the axle box. This construction has proved very durable, and some carriages have been at work on this plan six years, and show hardly any wear.

The usual mode of framing coach bodies is by mortice and tenon; but by this method the foot of the pillar, where most strength is required, is weakened, as is also the bottom side into which the mortice is made; and from the wet getting in, the pillar becomes rotted at the foot, the part that requires most strength. In place of this construction the writer has adopted the plan with third class carriages, shown in Figs. 7 and 8, of securing the standing pillars to the bottom sides with corner knees and double clips, retaining the whole strength of the pillar at the foot where it is most required, and not weakening the bottom side with mortices. By thus letting the framing stand prominent, one panelling becomes sufficient instead of two, the boarding $\frac{5}{8}$ inch thick being fixed crossways and screwed at the ends into the pillars; this makes a very strong plain body and without any mortice for the water to lodge in.

It has often been considered that agriculturists were in fault for being slow in adopting improvements; but still they have their ploughing matches, their cattle shows and trials of implements, and it is well known what extensive improvements have been the result: the writer has often thought that railways might with very great advantage take a lesson from them and have their shows of rolling stock. It may be said that the gradients of various lines differ so much that an engine suitable for one line is not suitable for another; but without touching that part of the subject, the writer thinks it will be admitted that, however lines may vary, the passengers do not, and that a good carriage on one line would be so on another. What the writer would suggest is to have a show of rolling stock say every

three or four years, and to let the railway companies contribute to a common fund for the prizes; this would stimulate exertion, and not only lead to improvements, but cause them to be more generally known. If there were a prize to be obtained, every contributor would be anxious for all to see and know his improvements, and would be ready to point out any disadvantages in other vehicles. The result would no doubt be a very great saving, avoiding sometimes very large expenditure in trying over again plans that other companies had already tried and rejected, the result being a mutual advantage to all concerned.

Mr. McConnell considered the subject of the paper was an important one, and deserving more general attention than it had yet received; he was satisfied that much might be done in reduction of the working expenses of railways by reducing the dead weight of the vehicles forming the trains, and thought a valuable step had been taken by Mr. Fay in the improved construction of carriages described in the present paper. He had had his own attention much drawn to the subject, and had tested the principle by constructing a long carriage some years ago capable of holding 84 passengers. He had been led to this by consideration of the enormous cost incurred in hauling dead weight, so much in excess over the actual loads carried, making it an important object to reduce this dead weight, as even a small fraction off the whole would produce a considerable amount of saving in the unprofitable expenses. When the total mileage of the carriages during their lifetime was considered, the total waste of power in constantly hauling an unnecessary weight of 7 tons per train was seen to be very serious. The speed of trains now being something like that of the bird, the construction should also bear more analogy than at present existed as to the use of the lightest materials in the strongest form. In the carriage he had tried, he had adopted wrought iron framing and tubular axles with a view to carrying out this principle, with decided success and advantage; it was an important question to consider what material was the best to use for the frame, and he was inclined to prefer iron, but there might be objections to it. The proposal of a periodical exhibition of

railway carriage stock was he thought a good suggestion, and would be likely to lead to good results, by comparing the experience and opinions in different districts. The principle of large sized carriages had been most completely carried out on the American railways, where the proportion of dead weight per passenger was much less than in this country; but a greater expense here was unavoidable on account of the difference in the habits of the people, which did not admit of the large omnibus fashion of travelling being generally adopted on railways. The system of carrying luggage on the roof he quite agreed was decidedly objectionable, and he thought the adoption of end compartments for luggage was a good suggestion; if the luggage could be placed below the carriage body it would be a still better place, as lowering the centre of gravity, but that would probably be impracticable from the difficulty of access.

Mr. Fay said he had tried to effect that object, as under the carriage was decidedly the best place for the luggage if practicable; but he had been obliged to abandon the idea, because at all stations except the smallest the platforms were constructed nearly level with the carriage floors, so that luggage could not be got at from the platform if below the floor level.

The Chairman enquired how it was that but little weight could be saved in weight of roof, by not carrying luggage on the roof.

Mr. Fay replied that the roof had to be made strong enough to bear the weight of a man per square foot, to provide for the porters getting to the roof lamps, and it was then found to be strong enough for carrying luggage; and but little saving could be made in the strength of the sides to carry the roof. But though there was little difference in the cost of framing of the roof, an important saving was made in the material of the covering and cost of wear and tear, by not carrying luggage on the roof.

The Chairman observed that saving in weight had been much more attended to in America than in this country; they had specially attended to this in railway carriages, and he had been much struck with the lightness of the road carriages there, and had even seen one only one-third the weight of the man carried, the carriage weighing only 60 lbs. with two wheels 4 feet 10 inches high. In the case of a railway carriage or of any machine, it was a great mistake, he thought, to increase the weight when it broke in order to prevent it from breaking again, because the breakage occurred in most cases not from want of material, but rather from bad or improper material being used.

Mr. Slater had no doubt that long carriages were advantageous in saving dead weight, but they involved the serious drawback of being more inconvenient to handle in stations and requiring larger turntables; the present workshops would also not be large enough to take them in, and would require enlarging. Of course if the workshops had to be provided anew they might be built accordingly, but they had now to work with their present appliances. It would be decidedly preferable to avoid carrying any luggage on the roofs, if such an arrangement were practicable; but he doubted whether the proposed luggage compartments at the ends of the carriages would prove sufficient in many cases; they might answer for short lines or branch traffic, but in long trains such as the express from London there was at some seasons upwards of $1\frac{1}{2}$ tons of luggage for each of the 10 carriages in the train, and a van at least would be required to carry the luggage in addition to the proposed compartments in the carriages, which would abandon part of the intended saving. The suggestion of exhibitions of railway carriages he thought was a good one, and would be likely to prove advantageous and lead to permanent improvements in railway stock.

Mr. Fairbairn thought it very desirable to obtain the advantage of economising dead weight by the use of large carriages, and to aim at a maximum of strength with a minimum of material. As to the objection of requiring a large outlay for new turntables and alteration of shops, it would become simply a question whether the interest of this outlay would be paid by the saving in cost of working; that might be calculated, and he expected it would leave a large balance of saving in favour of working the fewer number of large carriages.

Mr. Fay observed that the expense of altering workshops and turntables would be found to be much less than supposed at first from comparison with the present system of working with short carriages. Turning the carriages had been practically abandoned in many cases without disadvantage; on the Lancashire and Yorkshire line they did not use turntables, but always shunted the carriages in and out at the terminal stations, the carriages returning backwards and never being turned; they had a traverser but it was seldom used, the work being more conveniently done by shunting; no difficulty was experienced in carrying out the plan, and there was found to be a saving of time and manual labour in avoiding the use of turntables. The difficulty of extra luggage would be best

provided against by making the luggage compartments large enough to carry the greatest ordinary quantity, leaving an extraordinary case to be met by a special provision.

Mr. Brogden enquired how it was proposed to provide for the requisite breaks in a train, if the guard's luggage vans were omitted.

Mr. Fay replied that the front part of the leading carriage was constructed with a guard's compartment, and fitted with a break, which he had lately invented, acting simultaneously on every carriage in a train or on as many as was desired, all being worked from one point where the guard was stationed. He was satisfied that was the correct principle, and not to depend upon one or two breaks alone for stopping the whole train. He had had the breaks working for the last six months upon the Lancashire and Yorkshire line, and the results obtained were highly satisfactory in the increase of safety and control over the train. In one case a train of two large carriages was stopped in 76 yards when going down an incline of 1 in 49 at a speed of about 20 miles per hour by the combined action of the breaks on all the wheels, and the engine being reversed; and in another case with the same two large carriages the engine was pulled up in 600 yards on a level with full steam on, by the application of the carriage breaks alone, without the driver being previously aware of the intention, the engine being a tank engine of ordinary power, regularly working the Ashton branch of the Lancashire and Yorkshire Railway.

Mr. Samuel Lloyd, Jun., asked what was the distance between the centres of the axles in the new long carriages; the use of carriages too long for ordinary turntables was extensively adopted in Germany; several lines there were worked entirely with long carriages, and engine turntables were employed for turning both carriages and engines, the tables being all about 26 feet diameter.

Mr. Fay replied that the longest carriages were 18 feet in the distance between the axles; these were four-wheeled however, and he believed the long carriages in Germany were six-wheeled, but he considered it an essential point in carrying out the idea of the long carriages to have them only four-wheeled, saving most of the weight of the third pair of wheels and their axle, springs, guards, &c., and allowing the carriage to run on ordinary sharp curves.

Mr. H. Woodhouse thought that with such very long carriages as had been proposed a great difficulty would be experienced at the stations

in handling the carriages, and an increased staff would be required; the system of shunting the carriages instead of turning them could only be carried out at terminal stations and junctions, and a great outlay in large turntables as well as in alteration of shops would still be required. With the greatest portion of the first class traffic in this country it was unavoidable to have a considerable excess of space and dead weight to meet the requirements of the passengers' comfort.

Mr. Fay observed that the comparison in the paper had been made with equally comfortable carriages, having only six passengers in a body; the difference in proportion of dead weight was made only in the greater number of bodies on one frame, which would not affect the comfort of the passengers, whilst the luggage being carried in each carriage in compartments at the ends would certainly add much to it. A saving of 5 to 7 tons weight at least was thus effected in ordinary trains of 5 to 8 carriages, and the same proportion in larger trains.

Mr. Fairbairn considered that from that proportion a saving of as much as £20,000 per annum would be effected on the London and North Western Railway alone; and this would be attained by a saving in the cost of locomotive power for dragging that extra load in every train, which would be enough to pay for very extensive alteration of stations and shops, probably considerably more than would be found needful.

Mr. Slater observed that in reference to carrying luggage on the roofs of the carriages it was admitted to be a decidedly objectionable plan; and separate vans were employed in the through trains; but for branch traffic and other local cases it was at present necessary to put the luggage on the roof in order to carry it with the carriage. The proposed luggage compartments would certainly be advantageous in these cases; but he did not think the present luggage vans could be dispensed with altogether without encroaching too much upon the space for passengers in the carriages.

Mr. J. Wright, Jun., quite agreed in the objections to carrying luggage on the roof, and had found it cause a great increase in the cost of repairs, from the wear and tear of the roof and the damage done to the sides and windows of the carriages in getting the luggage up and down; the plan was adhered to however upon many railways on account of the convenience for classifying and separating the luggage for different branches and junctions. The plan of luggage

compartments at the ends of the carriages would certainly meet the case, if not found too expensive a mode of construction; but he believed this plan had been tried and afterwards discontinued in some long carriages on the South Eastern Railway. He thought that it would prove a considerable advantage in the improvement of railway carriages if opportunities were afforded the makers for carrying out improvements that their experience pointed out as desirable.

The CHAIRMAN proposed a vote of thanks to Mr. Fay for his paper, which was passed.

The following Paper, by Mr. Thomas W. Dodds, of Rotherham, was then read:—

ON IMPROVEMENTS IN STEEL MANUFACTURE, AND ITS APPLICATION TO RAILWAY AND OTHER PURPOSES.

The process now generally adopted for making Steel is to place the iron in the converting furnace in alternate layers with ground charcoal between the layers, and when the pots or chambers are filled they are covered with earthy matter that will resist fire, such as sand, loam, or what is sometimes called wheel swarf, to exclude the atmosphere; the openings of the vaults are then bricked up and plastered, the fire is lighted under the furnace, and the heat which requires to be strong is kept up from 7 to 9 days. The furnace is then allowed to cool sufficiently to enable the men to enter the vault for the purpose of discharging from the furnace the converted iron, which has now become Blister steel; and the whole process, including the time of getting up the heat in the furnace, the time requisite for conversion, and the time taken in cooling to enable the men to discharge, varies from 16 to 19 days. Cast steel is blister steel broken into small pieces, put into a crucible together with certain proportions of manganese, and placed in the melting furnace for about 4 hours on an average, according to the size of ingot or temper of the steel required; it is then cast into ingots, and is ready for hammering or rolling. Shear steel is made from a milder blister steel, by being piled or faggotted and then heated to a welding heat and welded under the hammer or tilt; Double Shear is produced by re-faggotting the above shear steel, and welding and hammering in the same manner.

The author of the present paper, following out a series of experiments that had for several years been carried on by his father, and after the usual alternations of failure and success, devised a furnace that admitted of being charged and drawn without interfering with the heat of combustion, or very slightly so, thus saving in the first instance the time required in the old process of waiting for the cooling of the furnace down to a point that would enable the men to enter; also, by a modification in the chemical materials of

conversion, he has been enabled to effect a more rapid action. The result obtained is that the firing, which in the old process was continued from 7 to 9 days, need not be kept up longer than from 3 to 5 days, the furnaces in each case being of similar size and operating upon similar materials. The commercial advantages sought for were here arrived at; namely, an economy in coal of 50 per cent., and a much greater economy in time, without detracting in any degree from the quality.

The process by which the blister steel specimens exhibited to the meeting were produced was by covering the iron in the furnace with charcoal, mixed with a small portion of about 6 per cent. of lime and about 2 per cent. of alkaline matter, generally soda-ash, and then exposing the whole to the strong heat of a fire of ordinary coal for 75 hours or $3\frac{1}{8}$ days; the iron was then drawn from the furnace which had been somewhat reduced in temperature, and the conversion was completed. It is to the arrangement of the furnace in such a form as will enable the iron to be placed and withdrawn for an indefinite number of charges with comparatively slight reductions of heat, that a considerable portion of the economy is due; for it is manifest that each furnace is thus rendered at least four times as productive as under the old or more usual process; and, besides the greater quantity of work that may be carried on within the same area of ground, it is only chargeable with one-fourth of the present amount of interest or fixed capital invested in furnaces. This will be an important consideration in the establishment of any new works that may be erected for carrying out steel manufacture, and will in fact form the nucleus of its commercial expansion.

It has been a great point often aimed at as an obvious improvement in the iron manufacture to increase the hardness and durability of the working surface; and endeavours in this direction resulted in various contrivances more or less applicable. Perhaps the best recognised efforts were the chilling of cast iron railway wheels, which produced on them a hard wearing surface, owing to the rapidity with which they were cooled. This method of hardening was carried out to a great extent in the wheels used by railway contractors for the temporary earth wagons employed in the first construction and for the locomotives and carriages of the earlier railways. Casehardening was a different process, which depended on chemical properties and

action, the exterior surface being brought to a quality approaching to steel of a superficial nature. The next attempt was the welding of a bar of steel on the wearing surface of tyres; and other experiments were made in the same direction by Mr. Sidney Jessop, who, expending much time and money in various experiments, produced the further advance of submitting portions of the iron where hardness was essential, such as wheel tyres and rails, to the continued action of carbonising fuel, producing a steel surface. This effort of Mr. Jessop led to the series of experiments on which is based the process described in this paper, the results of which in the production of pure blister steel have been mentioned; it has also in its progress suggested other results of some importance.

The conversion being progressive from all sides of a bar towards the centre, it could of course be arrested at any given point of its progress by withdrawing the bar from the furnace, the bar would then possess an outer coating of pure steel of any depth that may be required, and an internal core of tough unchanged wrought iron, offering a material that for many purposes would be far preferable to either of these materials in their single form, combining the hardness of steel with the tensile strength of malleable iron; and as but a comparatively short time is necessary for this partial conversion, the increased durability is further recommended by its cheapness. This process is applied to hardening the wearing surface alone of rails and tyres, by placing sand in contact with those parts of the bar which are not required to be hardened.

Taking as an example of the application of this process the important case of railway bars: if the surfaces were protected from the wear of the wheels rolling over them by a coat of hardened steel $\frac{3}{16}$ inch thick, there can be little doubt that a rail thus encased in steel would last three times as long as the ordinary rail, and it would still retain its tough core of wrought iron and for all the purposes of a rail would be better than if formed of either material alone. Then to form an approximate estimate of the commercial result to the railways of this country: the extent of these railways may be taken at 8000 miles, each yard of double way containing about $\frac{1}{8}$ ton of rails, a mile 220 tons, or 8000 miles 1,760,000 tons; then the rails cost at £8 per ton £14,080,000, and they want renewing say every 7 years. If the rails with steeled surfaces last three

times as long, their life will be 21 years. Hence the total account on this item would stand thus for a period of 21 years:—

By the present wrought iron rails three renewals at a cost of £14,080,000 each would be	£42,240,000
Deduct value of two sets of old rails at half price ...	14,080,000
Total cost to the shareholders in 21 years	28,160,000
Steeled rails at £9 10*s.* per ton	16,720,000
Saving in rails alone	£11,440,000

As two relayings are saved, we might fairly take credit for the saving of one set of sleepers and one relaying:—

Sleepers for 8000 miles, 28,000,000, at 4*s.* per sleeper...	£5,600,000
Laying 28,000,000 yards at 1*s.* per yard	1,400,000
Saving in 21 years	18,440,000
Saving per annum	£ 878,095

This amounts to a saving of £110 per mile per annum, a very important addition to the resources of any railway. In the case of foreign railways, where freight from England adds to the cost of the rails, there would be a further saving of two freights of the rails every 21 years: suppose freights and inland carriage are £5 per ton, which on two relays in 21 years would be 10*s.* per ton per annum; this would make another £110 per mile profit, and it would thus appear that in foreign railways, where freight and inland carriage amount to £5 per ton, the economy resulting from the increased durability of the rail would actually amount to £220 per mile per annum, a sum approaching to half a dividend. It is by no means expected that the improvements aimed at, which all the experiments show to be practicable, will at once change the existing economy of railways and produce a sudden revolution which will raise the value of the property and the hopes of the shareholders; the tendency is in this direction, and these are the ultimate results; and though the full results could not be looked for till after the lapse of years, yet it is natural for all who contemplate improvements to look at the end to which they lead, and the ultimate results which in the course of time may be attained.

In connection with railway bars the important and expensive item of points and crossings may be mentioned, which if subjected to the above process will show a very marked reduction in the expense of their maintenance. At some heavy goods stations they are at present a peculiarly

costly item; but when coated with a surface of hardened steel they will manifestly withstand to a very much greater degree the shocks and jerks of the passing loads, and their working would to some small extent be facilitated.

The idea naturally occurs that the same process may be applied to various articles, partially or otherwise as their intended use may suggest. In good English or Welsh malleable iron we have a material of unchallenged excellence; and if to its own good properties we could add when requisite and to any required extent the properties of steel, we should then possess a material which for practical purposes would be more useful than either of the single forms, steel or malleable iron. The author has endeavoured to effect this at a cost that should make it commercially available, and some of the results obtained are shown in the accompanying specimens, consisting of—blister steel made in 75 hours—two sets of railway bars, showing partial conversion after being in the furnace 56 and 70 hours respectively—cast steel made from the above blister steel, and from Welsh iron similarly converted—files made in wrought iron and afterwards converted—and portions of bars showing partial conversion. The raw material is in all these specimens good wrought iron; and the change produced upon it by conversion, as exhibited in the series of fractured bars, shows a development of steel in all gradations, from a film $\frac{1}{16}$ inch thickness to the entire conversion of the whole bulk.

The furnace used is shown in Plate 127; its principle of arrangement is to keep up the fire till the want of necessary repairs requires it to be burnt out, and it is divided into compartments, ovens, or retorts, in which the articles can be placed and withdrawn at pleasure.

Figs. 1 and 2 show a single furnace with an oven or retort open at one end only; and Figs. 3 and 4 show a double furnace with two retorts, each open at both ends: the same letters refer to the corresponding parts in both furnaces. A is the firegrate below the retorts BB, and communicating with a series of flues CC passing up both sides of the retorts into the dome D, from which the openings EE lead into the chimneys F, one chimney being placed in the centre of each side of the double furnace, giving a uniform distribution of the heat over the furnace. In all portions exposed to the heat the interior is constructed of firebrick or similar material.

In the furnaces in use for converting rails, a carrying apparatus

with a balanced jib is employed to place the rails in a horizontal position on the top of the material for converting; a series of rails is so placed, and a flat shovel is carried into the furnace, holding the material for carbonisation, and in being withdrawn the material is sprinkled uniformly over the rails to the depth of about $\frac{3}{4}$ inch; another layer of rails is then placed in the furnace and covered in the same way; and so on until the oven or retort is filled, when the door at the end is closed and clayed up, and the process of conversion at once commences, the heat of the furnace having been kept up nearly to the full temperature during the process of charging. In drawing the furnace, each layer of the carbonising material is raked into an iron box, and when full sprinkled slightly with water and the cover closed tight, so as to prevent waste from the action of the atmosphere; by this means the greater portion of the material is preserved for use in the next charge, and it is found that the same carbonising material serves for three successive charges with the addition of only about 10 per cent. of fresh material each time, thereby effecting a great saving in the cost of the process.

In some instances peculiar articles might require peculiar adaptations of the furnace; as for instance, in the partial conversion of wheel tyres, an important feature of the rolling stock, which when hardened will diminish to a great extent the tractive force required for propelling the trains: steel rolling on steel is a near approach to theoretical excellence. In connection with this are axle bearings, whether for engines, tenders, or carriages, for which the process of partial conversion is eminently adapted. Besides the application to these heavy articles, a large field is open of almost infinite variety. Tools for the workshop and articles of household use can be made from the material most easily worked, namely wrought iron, and afterwards turned into steel wholly or partially. Some of the best cutting tools now used by the author are made from wrought iron converted by this process. Shovels and all the endless variety of agricultural implements partake of the advantage, and, at a lower cost, will stand the work that a good tool would be expected to perform: made in wrought iron, converted, ground, and dressed, they take rank with the most expensive tools of the day, at a cost but little exceeding that of a very ordinary implement. Some specimens are shown of files prepared by this process; they were cut and completed in wrought iron, and then converted and hardened; for this manufacture the process is highly economical.

Mr. Dodds exhibited a number of specimens of the steel, and of bars and sections of rails converted to different depths by the process described in the paper; also of files converted after cutting.

The Chairman enquired whether many different kinds of iron had been used for the process of steeling the surface, and whether there had been found to be much difference in the quality of steel obtained, as to good cutting edge and satisfactory working quality; also what priced iron was employed.

Mr. Dodds replied that many kinds of iron had been tried, but with the British iron there was not any material difference in the steel produced. Welsh iron of ordinary quality, at about £9 10*s.* per ton, was found to make good steel, and the whole process of conversion added only £1 per ton, making it a very economical manufacture.

Mr. Ramsbottom enquired whether the iron was not found to open sometimes in the process of conversion, and so spoil the finished surface and unfit it for the work intended.

Mr. Dodds said that sound iron was found to stand the process perfectly without any injury to the surface, even in the case of the teeth cut on a file, as shown by the specimens exhibited; but if the iron was not sound it was certainly shown by opening in the process, and this gave an advantage in detecting defects in the iron that would otherwise escape notice.

Mr. McConnell asked whether any large wheel tyres had been steeled by the process; that was a very desirable object to be satisfactorily accomplished without risk of fracture or involving too much expense. Steel tyres were now in extensive use in Prussia for locomotive wheels, made entirely of steel of a peculiar quality, and their durability was said to be very great, amounting to even 250,000 miles for a set of tyres; there would be a great saving in total expense in that case, even at a considerable increase of first cost. The plan now described of converting the wearing surface of the tyre had the advantage of much less cost, and uniting the toughness of a wrought iron foundation with a hard steel face.

Mr. Dodds replied that twelve sets of wheel tyres steeled by conversion were at work on the Caledonian Railway, and had been running there a long time with complete success; also some coupled engine tyres on the Midland Railway. A trial had been made with rails at the

London Bridge station, where a number of the steeled rails had been down in situations exposed to the heaviest traffic 18 months with little perceptible wear, where ordinary rails lasted only 3 months.

Mr. Samuel Lloyd, Jun., remarked that the use of steel facing for rails had been extensively adopted for many years in making points and crossings, with great advantage in increase of durability; a steel bar was welded upon the top of the rail in the process of manufacture by inserting it in the pile from which the rail was rolled. Another and cheaper plan had also been adopted on one or more occasions; the iron for the crossings had been placed in an ordinary converting furnace of a steel works, and the surface had been converted into steel similar in appearance to that now produced by the furnace described in the paper, at a cost of about £2 to £3 per ton.

Mr. Dodds said the plan of partially converting the wearing surface of the rails after the rolling was completed in the ordinary way had a considerable advantage in the economy of the process, and in avoiding all risk of unsoundness between the steel and the iron, which sometimes caused steel faces to become detached in course of work. The process had been in course of trial for many years previously by Mr. Jessop, but the practical difficulties had not been overcome so as to bring it into working order until the recent improvements described in the paper, the process having been previously found too expensive and liable to inequality in the hardness of the surface obtained. The great saving now effected in the cost arose from reducing the time of the process to about one sixth of that required before; and the uncertainty in the process had now been quite got over, so that the surface of bars could be readily steeled to any desired extent with complete certainty.

The Chairman enquired whether the files had been much used, and what were their results in working.

Mr. Dodds replied that they had been 4 years in use in engine shops at Newcastle, and had been fully approved; they were made of ordinary scrap iron, some of Welsh and some of Staffordshire iron, each file being made and cut complete before conversion; and the cost of conversion was only about $\frac{1}{8}d.$ per file.

Mr. McConnell asked whether there was not found to be a difficulty in the manufacture, from the files warping and twisting in conversion, on account of their irregularity in thickness.

Mr. Dodds said the half-round files were liable to twist and bend, but not to any objectionable extent, and they were readily straightened on taking them out of the converting furnace; the flat and round files remained straight.

Mr. Humber thought the steeling process would prove an important gain for rails, as the present cost of permanent way maintenance caused by the wearing out of the surfaces of the rails formed a large item in railway expenses; a more durable material for the wearing surface of rails had long been a desideratum, but the objections of cost or of imperfection in manufacture had hitherto been too serious. He asked whether, taking the duration of ordinary rails at 7 years, it was intended to calculate the durability of the steeled rails at 21 years, as it was stated to be three times as great.

Mr. Isaac Dodds said the present experience of the rails appeared fully to support that conclusion; he had lately seen the steeled rails that had been referred to, and they appeared quite fresh after the 18 months' work that they had had; the fact of the rails lasting was indeed a question only of the comparative duration of steel and iron. The lamination of the surface was the great source of destruction in common rails; but this was avoided in the steeled rails, as they did not laminate on account of the crystalline structure of their surface. If there was any imperfection in the manufacture of the iron, it became exposed in the converting process and was rejected, giving an advantage in ensuring soundness. If the rails would bear the further expense of rolling again after conversion it would give a still better result, and he was inclined to think it would more than repay the expense; for in the case of ordinary blister steel its quality was much improved for work by being condensed by hammering or rolling. The deflection of the rails under a load was found to be greatly reduced by the conversion of the top surface, from the greater stiffness of the steel portion: in a trial that was made, a bar $\frac{3}{4}$ inch square and 22 inches length of bearing before conversion deflected $4\frac{1}{2}$ inches with 11 cwt. load, and bent in between the supports; but after the conversion of the bar to a depth of $\frac{1}{16}$ inch from the surface it deflected only $\frac{1}{8}$ inch with the same load, and broke at double the load. In the case of rails an important reduction would be effected in the cost of traction upon railways by the reduction in the deflection of the rails under the weight of the trains. In the ordinary make of rails, turning or reversing the rails was generally

found impracticable, the surfaces being so soft that they became indented by bearing on the chairs; but if the rails were hardened this would not occur, and they would admit of turning. There were several other applications of the process that he expected would prove very useful, such as steeling the surface of piston rods and valve rods of steam engines, where the durability and fine wearing surface of steel would be obtained at a small expense.

Mr. HUMBER observed that if the steeled rails showed no signs of wear after so much work it was certainly strong evidence in favour of the efficiency of the plan; and their increased strength would be a great advantage in allowing of lighter rails being used.

Mr. SAMUEL LLOYD, Jun., asked what was the chief peculiarity in the arrangement of the converting furnace.

Mr. DODDS explained that the ordinary furnace pots containing the bars to be converted were closed at both ends, having flues ascending at the ends; but in the new furnace a doorway was constructed at each end of the pots, by means of which the iron could be withdrawn at either end, admitting of drawing the charge and re-charging without letting down the heat of the furnace as was requisite in the ordinary furnaces in order to enable men to get inside the pots.

The CHAIRMAN proposed a vote of thanks to Mr. Dodds for his paper, which was passed.

The following Paper, by Mr. Benjamin Fothergill, of Manchester, was then read:—

ON RECENT IMPROVEMENTS IN WATER METERS.

The activity which has recently been displayed in the invention of various improvements for measuring water is one of the best proofs of the importance of the subject. It has been recently remarked in a well known scientific journal, when reviewing various inventions for measuring water, "that a cheap, simple, and compact meter, that will under extreme circumstances register with exactness, and present no appreciable obstruction to the flow of the supply water, is still a desideratum." In 26 years, from 1824 to 1850, 13 patents were taken out for improvements in water meters; and in $6\frac{1}{2}$ years, from 1850 to the present time, 61 patents have been taken out for the same purpose. The increase and extension of water works, to meet the requirements of the public under the improved mode of constant supply at high pressure, have rendered an efficient measuring apparatus a matter of great public importance.

The use of water meters may be considered in three aspects; firstly, as affecting water works companies as sellers of water; secondly, as affecting the public generally as purchasers and consumers of water; and thirdly, as specially affecting mechanical engineers in testing the various descriptions of boilers and fuel in the production of steam.

The water companies, as trading concerns, are able to provide certain quantities of water at fixed prices according to their respective scales; and so far as regards the supply to dwelling houses, the charges usually made according to the rental would be satisfactory, provided leakages could be obviated or detected. But it has been found that the waste of water by leakage, even in house services, arising from wilful neglect or carelessness, is so great as to call for some urgent means to prevent so serious a loss. Water meters applied to the main pipe supplying blocks of buildings, and in some cases to separate dwellings, would therefore be desirable.

In all supplies of water for manufacturing or other business purposes, it is now generally admitted that the only equitable and satisfactory arrangement is to charge according to the quantity actually used; and this can be done only by using a water meter. The charge for water supplied by meter generally ranges from 3*d.* to 1*s.* per 1000 gallons, according to the quantity used; but in Manchester it is from 3*d.* to 1*s.* 10*d.* The excessive price charged to

small consumers has no doubt been occasioned by the frequent loss by leakage in such cases: the general adoption of water meters would no doubt induce the authorities to remove this apparent anomaly. On the supposition that the generality of consumers pay 1*s.* per 1000 gallons, the desirability of measuring the water used in all such cases is the more apparent by comparing the rate of charge with that for gas, which is now universally sold by meter. The average price of gas may be taken at 4*s.* 6*d.* per 1000 cubic feet; but the price of water at 1*s.* per 1000 gallons is 6*s.* 3*d.* per 1000 cubic feet. Water is therefore of greater value than gas, and there would appear no reason why water meters should not be as generally used as gas meters, if an equally efficient measuring apparatus, combining the requisites of cheapness, efficiency, durability, and portability, were devised.

The use of a reliable water meter to mechanical engineers, in enabling them to test with accuracy the evaporating power of various constructions of boilers and flues, and the value of the different varieties of fuel, is so palpable as to require no further reference thereto.

Water meters may be classified as low pressure and high pressure meters.

The best low pressure meters are in many respects unsatisfactory; they require to be fixed along with small cisterns on the top of the highest part of the building in which the water is required, and the pressure from the main being cut off, the quantity of water discharged is consequently small; and great inconvenience is occasioned in examining them. The cost of such meters in proportion to their measuring capacity is also considerably greater than that of high pressure meters. In consequence of the acknowledged inefficiency of all low pressure meters, few material practical improvements have lately been attempted in them, the attention of engineers having been directed to obtaining a correct and durable high pressure meter capable of registering the quantity of water delivered without lessening its pressure or velocity.

High pressure water meters have been classified as "inferential" and "positive" meters. The inherent defect in "inferential" meters, of allowing small quantities of water to pass without registration, is an objection to such machines which no superiority of work can remove; and this defect is found to exist even in the best contrivances of this class, notwithstanding the skill and ingenuity displayed in

their manufacture. Of "positive" meters, or those which measure by capacity, many machines have recently been constructed on the principle of the diaphragm; but in consequence of the impossibility of finding any flexible material sufficiently durable for the constant wear required, they have not been brought into general use.

The nearest approach to practical efficiency amongst those using a flexible material appears to be attained in the rotary meter invented by Mr. Chadwick, consisting of a prepared leather or vulcanised india rubber diaphragm, upon which a wheel works mounted on an axis, with moveable rollers attached to its periphery. But although these meters measure correctly and some are still in use, they have not been found satisfactory in regard to their durability where they have been subject to excessive wear and tear. Other diaphragm meters are peculiarly liable to the objections of unequal distension of the flexible material and excessive wear; and have consequently not been practically brought into use.

All other "positive" meters may be considered as modifications of the piston and cylinder principle. In the piston meters which appear to present a practical fitness for use, one plan has two cylinders and pistons working a crank at right angles, with a composition of gutta percha and black lead for the packing of the pistons. In another plan, a piston and cylinder motion is employed for shifting the valves, which is obtained by employing two cylinders and pistons working in an outer case, and so contrived that the piston rod of one cylinder shall move the valve in the other cylinder, the piston rod of which is operated in like manner. Thus an alternate reciprocating action is maintained, by which a constant stream of water is delivered. The main practical objections to these contrivances are the bulk and weight of the machines, arising from the space which is required by having two separate cylinders and pistons, whilst only one can be actually in use in discharging and measuring the water; and the necessity for an additional outer case, which must be of sufficient strength to resist the pressure.

In the piston meter recently brought before the Institution, by Mr. Kennedy (Proceedings Inst. M.E. September, 1856), a cylinder is used with a piston and rod working vertically; to the piston rod is attached a rack, working into a toothed wheel connected with the inlet and outlet valves, which are on the principle of a four-way cock. The change of the valves is produced by a weighted lever,

which is moved and thrown over at each stroke of the piston; and this weight is required to be sufficiently heavy to overcome the resistance of the pressure of the water on the valves. A rolling piston packing of vulcanised india rubber is used, and has been found peculiarly well suited and durable. The two distinguishing features of this meter are the racked piston rod and the rolling packing. As this meter has met with a large amount of success, it may be useful to refer to the objections which practical engineers have felt in regard to it, and which experience has confirmed, in order to ascertain the parts susceptible of improvement: these objections are—the great weight and size; the liability to stoppage by the sticking of the tumbling lever when the valve is partially closed, and thus allowing the water to pass without being registered; and the necessity for lubricating and packing various parts of the meter, which entails constant inspection.

In the piston meter recently invented by Messrs. Chadwick and Frost, of Manchester, the most important improvements have been effected, and the difficulties connected with the previous contrivances appear to have been satisfactorily removed by the application of a compound fluid motive valve, actuated by the direct pressure of the water, but not concerned in the measurement. This meter is shown in Figs. 1 to 4, Plate 128, and consists of a measuring cylinder A, and a piston B with either a cupped leather or india rubber rolling packing, as shown in the drawing, and a valve chamber C. The piston has no rod attached, but when in motion the ends come in contact with a catch D at the termination of each stroke; the catches DD form the ends of a bar E communicating from the measuring cylinder to the valve chamber, and passing through a stuffing box at each end. When this bar is moved, it reverses the position of the small circular valve F, and admits the water into one of the cups G, which forces out a disc to which is attached the principal valve H, which is thereby moved in position, and the direction of the water changed to the other end of the measuring cylinder, and thereby a regular and continuous flow of water is effected without any concussion in the pipes.

This meter is only about half the bulk and weight of any piston meter previously in use; it has fewer parts and less wearing surfaces than any other; it requires no lubrication and has no tumbling weights; it works smoothly, and without any offensive noise, and is not liable to allow any leakage by the sticking of the cock half over the ports:

and under all circumstances this meter has been found to register with a nearer approach to absolute correctness than any other. The writer being engaged in making a series of important experiments for testing the relative value of various kinds of coal and coke in the several descriptions of locomotive engines, has given the preference to this meter for the purpose of measuring the water evaporated, finding it the most exact and reliable apparatus for measuring the water used.

One of these meters is exhibited at work in the adjoining room, and a large one, for a 2 inches bore of pipe, constructed to measure 8000 gallons of water per hour, is to be seen and tested at the Water Works Yard, Salford.

Mr. FOTHERGILL said he had been led to try various water meters for the purpose of measuring the evaporation of water in locomotive boilers, but he had not found any accurate enough in measuring the quantity driven through them by the intermittent strokes of the feed pump at varying velocities; he was consequently obliged to give up the attempt to use a meter for the purpose, and to be content with measuring the water by gauging the depth in the tender tank. He had since had an opportunity of testing the meter now described, and found it more satisfactory than any other that he was acquainted with; and it appeared to him that the difficulties ordinarily experienced were ingeniously removed. A continuous flow of water was maintained through the meter, however slow the rate of discharge might be, by means of the auxiliary slide valve worked by the pressure of the water; this prevented any risk of the valve sticking on the centre and allowing water to pass without measurement, which other meters had been liable to. He thought the contrivance was very efficient to take off the shock that was generally experienced in piston meters at the change of stroke, and to ensure a steady and continuous motion of the meter. In the trials that he had made with this meter, the quantity of water passed was tested at various rates of discharge and different pressures, and in no case did he find an error of so much as one per cent. The meter was afterwards turned half round so that the water flowed through it in the opposite direction, and the top cover taken off; and whilst the meter was open all the results of the testing were very satisfactory.

The CHAIRMAN enquired whether there was found to be any difference in the correctness of measuring under the extreme conditions of a small and a large stream of water flowing through the meter.

Mr. FOTHERGILL replied that no difference was perceptible; whether the water was running very slowly, or as quickly as the full size admitted, the meter was found to measure quite correctly in both cases. The cock was nearly closed so as just to allow a perceptible flow of water, and afterwards set quite open at 80 lbs. per square inch pressure, and the meter was found to measure correctly in both cases. The simple principle of alternately filling and emptying a constant vessel was completely carried out, and this appeared to him the most perfect principle for the construction of a water meter.

Mr. HENRY MAUDSLAY asked whether the meter had been tried with the pipe discharging full bore, measuring the largest stream the pipe was capable of passing.

Mr. FOTHERGILL replied that it had been tried with a pipe 4 inches diameter supplying a 2 inch meter, and it was still found accurate in measurement.

Mr. GREEN asked what effect heat would have on the india rubber packing of the piston in measuring hot water to feed a boiler; whether the packing would not be liable to be injured after much exposure to the heat.

Mr. FOTHERGILL did not think there was any injury to be feared from that cause, as the india rubber was prepared to stand a considerably higher temperature than it would be ever exposed to in working; that kind of packing had been well tested by the experience of some years' working in Kennedy's meter, where it had been found quite satisfactory in measuring hot water to supply boilers.

Mr. T. FORSYTH enquired how long the meter had been at work, and whether long enough to afford sufficient experience as to its durability and permanently keeping in accurate order.

Mr. FOTHERGILL replied it had been only two or three months at work at present; but he thought the principal wearing parts of the apparatus had been so fully tested in the working of former meters, and the new portions in the present meter were so simple in construction and free from liability of derangement that there did not appear any reason to doubt its continuing to work as well as at first.

Mr. T. Forsyth thought it would be impracticable to ascertain satisfactorily the value of any water meter, until it had had a long continued trial in actual work under the various extremes to which meters were exposed in practice; there were many disturbing circumstances arising from corrosion and sediment in the water and other causes which did not show their effect till after a considerable time of working. He thought it was impracticable to compare a meter only a short time started with those that had been long at work, since it was not only correctness of measure at first that was required, but also permanent accuracy after long continued working.

Mr. Chadwick observed that although the new meter had been only a few months at work, and was not really in regular use at present, he thought there were means for readily judging of its durability from the nature of the material used; the principal wearing part, the rolling packing of the piston, had been proved by long experience in another meter to be thoroughly successful for this purpose. He had given many years' attention to the subject, and had experienced in his own connection with water works the want of a satisfactory meter suitable for general application, and the many difficulties in accomplishing the object; the results of numerous trials had led him to the adoption of the plan of the present meter, in which the water was measured by a simple cylinder and piston. By the use of a compound sliding valve moved independently by the direct action of the water pressure, instead of requiring any tumbling lever to pass the centres, he thought all risk was removed of the valve sticking partly open and either allowing the water to pass without measurement or obstructing the flow of water through the meter. He hoped they would be able now to bring down water meters to general use, comparing in price with gas meters; this was considered a great desideratum, as the more expensive construction of water meters had hitherto very much limited their application.

The Chairman proposed a vote of thanks to Mr. Fothergill for his paper, which was passed.

The following Paper, by Mr. John Ramsbottom, of Manchester, was then read:—

DESCRIPTION OF A SAFETY ESCAPE PIPE FOR STEAM BOILERS.

The object of the present paper is to describe an improved mode of applying the ordinary fusible plug to steam boilers, so as to secure the greater certainty of its action, and thus to remove one of the principal causes of boiler explosions, namely that arising from shortness of water. This plan is the invention of Mr. Routledge of Manchester, and it occurred to him that if the fusible plugs were inserted in a small flue or pipe, through which a current of the hottest gases, taken immediately from over the fire, was made to pass, this pipe being at the time at a higher level than the boiler surface over the fire, the fusible plugs would be melted out with greater certainty than in the ordinary arrangement, whilst at the same time the boiler not being overheated would be preserved from risk of injury.

The following is a description of the mode in which this idea has been carried into practice.

Fig. 1, Plate 132, represents a transverse section of an ordinary cylindrical boiler, 7 feet diameter by 14 feet long, set up with the fire underneath and with a wheel draught. An elbow pipe A, in this case 4 inches diameter, is made the means of carrying a portion of the heated gases from the furnace to the side or exit flue; and the upper part B of this pipe is perforated with conical holes $\frac{5}{8}$ inch diameter, as shown enlarged in Fig. 2, which are filled with fusible metal plugs simply driven in. In this arrangement, should the water fall below the upper surface of the pipe, the fusible plugs being constantly exposed to the current of heated gases passing through the pipe are melted, and thus preserve the boiler from injury, by immediately opening a large area for escape of the steam. A small tray or shield C is fixed upon the top of the pipe immediately over the fusible plugs, for the purpose of catching the sediment from the water and preventing the formation of a deposit upon the ends of the plugs.

Fig. 3 shows the application of the plan to a cylindrical boiler with internal fireplace. In this case, the pipe A as in Fig. 1 forms a connection between the furnace and side flue, and the fusible plugs B being exposed to the current of flame passing through the pipe are melted out as soon as the water falls below the proper level, and long before the plates of the main flue can possibly be injured.

The pipe A may be made of wrought or cast iron, brass, or copper, but it is preferred of wrought iron or malleable cast iron. Several experiments have been made by the inventor upon one of his own boilers, similar to that shown in Fig. 1, to test the efficiency of the plan, and very satisfactory results have been obtained. In one case, where the pressure of the steam ranged from 40 to 45 lbs. per square inch, and the water level from 3 to 4 inches above the covering or top of the side flues, the water was blown off, in order to facilitate the experiment, until its level was not more than $\frac{1}{4}$ inch above the top of the pipe A. The furnace was then fired up with the view of evaporating the water as quickly as possible, and reducing it below the proper level. Through a spy-hole made in the brickwork the action of the fire was distinctly observed playing upon the plugs until they melted out. It was subsequently found that three of the plugs had given way, thus relieving the boiler from steam pressure, and gradually putting out the fire, whilst a sufficient quantity of water was retained in the boiler to enable the stoker to recommence firing with but little delay for replacing the plugs.

Mr. Ramsbottom showed a specimen of the escape pipe with fusible plugs fixed in it, and separate specimens of the plugs; also one that had been burnt out. He said he had seen the plan at work in a boiler and thought it a good idea for extending the utility of the ordinary fusible plugs, by greatly increasing their efficiency in area for discharge of steam when melted, and by protecting them from being impeded in action through the accumulation of deposit upon their ends, by means of their position and the small tray placed over them to stop the deposit; the plugs were also placed at a higher level than any other heated portion of the boiler, and being exposed to a through current of the hottest gases were more certain to be melted out before injury was done to the boiler than any other plugs which he had seen.

The Chairman asked what composition was employed for the fusible plugs, and what was the temperature at which they melted.

Mr. Routledge said that the plugs he used were composed of 9 parts of bismuth, 22½ of lead, and 22½ of tin, an alloy which would melt not only from the action of the heat passing through the pipe, providing the pipe was not covered with water, but likewise when the steam attained an undue pressure and consequent high temperature; the plugs being so situated that little or no sediment could possibly settle upon them, as they were high up in the water space, and well protected by the shield or tray to catch the sediment when setting down to the bottom of the boiler.

Mr. R. Roberts thought it was objectionable to place fusible plugs in tubes, as the joint between the plate and tube retarded the conduction of heat from the plate to the plug; he considered they should be placed in a large extended surface. He remembered a case of a boiler explosion occurring at Stockport where it was supposed the boiler could not have been short of water, since the lead plug which was fixed in a brass tube had its centre only melted out; but on examination of the plug in the adjoining flue in the boiler it was found in precisely the same condition as the other plug, although from the appearance of the plates they had been red hot all round the plug.

Mr. Wm. Smith enquired how long the same plugs had continued in use in any case in the new apparatus.

Mr. Routledge replied they had been 9 months in continuous use, and he had seen the plugs melt after being that time in use; they had been found to answer completely, without any case of failure having yet occurred. The plugs were driven into the solid material of the flue or the large pipe leading out of it, so that he thought they could not fail to have the full action of the heat.

Mr. Wm. Smith considered that in the action of fusible safety plugs for boilers it was a question of the conducting power getting interrupted after oxidation of the surface had taken place, and the metal could not then be melted by even a much higher temperature than was enough to melt it ordinarily. He had known a number of experiments that were tried with plugs of tin and lead for the purpose of ascertaining the extent to which this action took place; and it was found that after 10 months' working in the boiler they failed of being melted out, though they were not placed in holes or ferrules, but were fairly exposed to the same current of heat as the rest of the boiler plate.

Mr. SIEMENS thought that when the flame was striking past the ends of the plugs the heat was not fully communicated laterally to them, even when they were flush with the plate; but some fusible plugs were very ineffective where fixed in little recesses, because they were then in a quiescent atmosphere which was a bad conductor of heat and prevented the action of the heat on the metal. In such cases he could quite believe that the water might have been low and uncovered the plug, yet this little dome of stagnant air would cut off the heat from the plug, and it might fail to melt in time to save the boiler. If metal plugs were desirable to be used, the plan now shown appeared certainly the best mode; if the plugs were not left in so long as to oxidise and become infusible they would be sure to act, and the large total area exposed would greatly increase the effect of safety obtained.

Mr. I. DODDS remarked that he had made use of a plan many years ago for fixing lead plugs, not in a tube, which he thought was certainly objectionable, but in the centre of a raised disc, 9 or 10 inches diameter, raised about 2 inches in the centre, and fixed in the top of the boiler flue or firebox; this plan was found very effective for the object intended, as it raised the level of the plug, so that it might be uncovered first and give way, and still allowed a free exposure of the plug to the heat. He had been led to the plan by finding that the ordinary plate was changed round the plug and became crystalline and brittle; but after 12 or 18 months' working he found the lead plug generally became very hard and difficult to melt, and it was requisite to change it about every 6 months to ensure keeping it always ready for action.

Mr. WM. SMITH said that in the experiments he had referred to the plugs were tried in all the different positions practicable in the boiler, over the furnace, in the internal tube, and in the side flues, to ascertain the difference of effect; but in every case, even over an intense fire, it was found to be only a question of time as to when the plugs would fail to act; after 18 months their ends became coated with oxide and the metal became oxidised and corroded through one third of its thickness; and if exposed longer than 18 months the entire mass of the lead plugs became changed and lost its fusibility. Lead plugs should certainly not be continued in use so long a time, as they became quite untrustworthy.

Professor RANKINE had had an opportunity of examining a locomotive boiler in which the firebox was blown in at the crown,

and found there that the lead plug had remained sound in the crown of the firebox and was not at all melted, although the temperature must have been very high, as it was found that a pressure of 470 lbs. per square inch was required to make a similar boiler give way in a corresponding manner. He considered lead was not trustworthy for the purpose.

Mr. RAMSBOTTOM said that the fact of the lead plug not always melting showed that its action was interfered with by some non-conducting coating, and the ordinary plugs were liable to the formation of a protecting coating of oxide and deposit upon their surface after being long at work, which required the periodical renewal of the plugs to ensure their action. In the new arrangement of the plugs this could also be readily done as often as might be requisite; and there was then the advantage that the total area of discharge given by the number of plugs was so large as to be really efficient in discharging the accumulating steam when required.

The CHAIRMAN observed that the question appeared to be how long lead plugs could be relied upon as efficient and trustworthy; they could then be rendered practically safe by renewal regularly within the requisite time.

Mr. TOMLINSON said that after about 6 months' work they could not be considered safe; he had found as the general result of his experience that in locomotive boilers it was advisable to renew the plugs regularly after being about that time at work, and had adopted that as a rule; and he considered that the plugs could then be safely relied on.

Mr. CRAIG said he had met with two or three cases where locomotive fireboxes had failed from overheating, without the lead plug having melted; and had adopted a standing rule for no lead plugs to be left in beyond six months, which he found sufficient to ensure their continuing in an efficient state.

The CHAIRMAN proposed a vote of thanks to Mr. Ramsbottom and Mr. Routledge, which was passed.

The Chair was then taken by James E. McConnell, Esq., Vice-President.

The following Paper, by Mr. David Joy, of Leeds, was then read:—

DESCRIPTION OF A NEW HYDRAULIC ENGINE.

The form of hydraulic engine which is the subject of the present paper was originated by the requirement of a motive power for the special purpose of blowing the bellows of a large organ, and was not at the time intended to be applied beyond the single case for which it was designed by the writer. Several conditions were requisite in the arrangements: first, that the power should be supplied from some constantly accessible source; this condition at once pointed to water pressure as the only available power, and resolved the question into a hydraulic engine, required not only to give out a reciprocating motion, but to be capable of regulation down to the slowest possible speed without having a dead point; at the same time to be perfectly free from the shocks due to water in motion at high pressure.

The accompanying drawings in Plate 129 show the arrangement adopted to meet these conditions. Fig. 1 is a side elevation of the engine, showing the attachment to bellows; Fig. 2 a vertical section through the cylinder; Fig. 3 a vertical section through the valve chest; Fig. 4 a sectional plan.

A is the cylinder, with ports the same as in a steam engine cylinder, BB being the inlet ports, and C the exhaust. D is a common slide valve, working over the face of these ports, and moved by its attachment to a small double piston EE working in two small cylinders FF in the ends of the valve box G. H is the water main. The pistons EE are moved by the water pressure, which is let into and out of their cylinders alternately by a small four-way cock I; this four-way cock is moved by a lever J and a rod K which is attached to an arm on the piston rod; the rod is fitted with set nuts or tappets for adjusting the action of the four-way cock. In the outlet port of the four-way cock is a set screw L, by which the area of passage of that port can be diminished and the water retarded to any desired extent in its escape from the cylinders FF, and thus the motion of the valve D regulated. O is the attachment to the feeder.

On the water main H is a large ordinary stop cock M, to which is attached a lever N and rod S, connected to the reservoir of wind P, at such a position that when the reservoir is full, the cock M is closed and the engine at rest; but when the reservoir descends by the exhausting of the air, the cock M is opened by the weight R and the engine is set in motion.

Fig. 1 shows the normal position of the engine when the water is turned on, and the reservoir full; the engine then moves only at an extremely slow speed sufficient to supply the leakage of wind through the material of the reservoir. The moment wind is abstracted from the reservoir, its depression opens the cock M, and the engine is set in motion with a speed proportioned to the amount of the exhaustion. Thus the supply of wind is always in exact proportion to the demand, and overblowing and unsteadiness as in hand blowing are entirely prevented.

The peculiarities of the engine are, having a motion of the valve which can be regulated as to speed, so as perfectly to prevent any shocks from the water at the change of stroke, whatever may be the pressure of the water used; and also a motion of the valve which can leave no possibility of a dead point, however slowly the engine may be required to work. By reference to the drawings it will be seen that the four-way cock I receives a complete motion from the piston rod *prior* to the valve D (upon which the action of the engine depends) having any motion; hence the motion of the valve D is ensured *after* the piston has completed its stroke. We have therefore even theoretically an engine moved by a non-elastic fluid, without the assistance of momentum, but without a dead point.

The principles of the engine being settled and a perfect action obtained, it was still found that the need for greasing the slide valve, though required only once per month, was a detriment; and the next object was to remove even this necessity, and to produce a machine which would require absolutely no attention. Various metals of different degrees of hardness were tried in conjunction; also various methods of ensuring the lubrication or moistening of the rubbing surfaces; but the metals were always found ultimately to rub dry and bite or cut into one another. All this pointed to the necessity for a variety of material in the rubbing surfaces; say metal upon some totally different substance. The paper read before the Institution last year on "Wood Bearings" as applied to the screw shafts of steamers at once suggested

wood as the required material; and after two attempts at proportioning the valve, a completely satisfactory result was obtained. Glass was also tried at the suggestion of one of the members of the Institution, but was found to wear much more rapidly than wood. Specimens of the various kinds of valves are exhibited, and an engine sufficiently open to allow of examination of its parts. There is also one at work applied to the large organ at the Art Treasures Exhibition.

The above are only the results of numerous and varied experiments; and it would be impossible here to detail the trains of idea and experiment which led to these results, or individually to acknowledge the assistance rendered by those who have examined the engine or assisted in its construction.

The Chairman observed that the apparatus seemed an ingenious and useful arrangement for getting over the difficulty of passing the dead points smoothly and with certainty in using water pressure, and he thought it likely to prove applicable with advantage to many different purposes; he enquired what pressure was found sufficient to work the machine properly.

Mr. Joy replied that the lowest pressure at present working was 7 lbs. per square inch, and an engine was now working successfully in Glasgow with that pressure of water. The cost of the power was found to be only 1-10th of ordinary hand power in blowing the bellows of large organs, when 45 lbs. per square inch pressure was used; and the result was remarkable in the complete steadiness of motion. With a high pressure, such as 120 lbs. per square inch, a slower return motion of the valve was required to take off all shock, and by means of the set screw in the water passage the valve was easily regulated to any speed of return.

Mr. Wm. Smith thought the plan might be made a very valuable addition to the houses of chamber workmen, such as watchmakers and a variety of trades, for driving small machinery in place of hand power; in London and other towns there was a constant and considerable pressure of water, and great benefit would be derived from the application of this engine for the purpose, as it was ready for putting into action at any moment, without involving any preparation or waste of power, and was completely under control. The desirability of water power

for turning small machines had been long felt, but there was a want of a simple and effective machine for the ready application of the power under the various circumstances; but this practical difficulty seemed most completely and successfully got over by the present apparatus.

Mr. Pilkington asked what number of strokes per minute the machine worked at, and whether any considerable speed was practicable without causing an objectionable shock from the stream of water being checked.

Mr. Joy said the machines were working regularly up to 50 revolutions per minute, and at that speed the motion was so smooth and quiet that it could scarcely be heard at all; this depended only on the adjustment of the regulating set screw for the return stroke of the valve, which afforded the means of completely preventing any shock.

Mr. Pilkington did not quite understand how a completely uniform pressure of wind could be obtained in the bellows of an organ, from the reciprocating action of the water engine.

Mr. Joy explained that the rate of working of the engine depended entirely upon the demand, the supply of water to the engine being entirely regulated by the position of the loaded air reservoir forming the top of the bellows: so long as the rate of demand for air remained uniform the engine continued working at a uniform speed, keeping up the reservoir at a constant level; but whenever the demand for air was increased, the top of the reservoir sinking a little increased the water supply, and consequently the engine worked just so much quicker as still to keep up the level of the reservoir; on the other hand when the demand for air was less, a little rising of the reservoir top contracted the water supply, reducing the speed of the engine to the rate required: the whole of the apparatus being self-regulating like the governor of a steam engine. In the first organ to which it was applied it was found that, in consequence of the greater steadiness of the pressure of the wind, the instrument could be tuned in only two thirds of the time required with hand blowing.

Mr. W. B. Johnson said he had heard of the improved effect of the blowing by the engine from one who had experienced it, and informed him that the uniformity and steadiness in the supply and pressure of the wind was much improved by the application of the engine, giving a perceptible advantage in playing. In hand blowing a jerk was unavoidably given at the end of each stroke, which gave a slight irregularity in the force of the wind, distinctly perceptible in the sound.

Mr. Pilkington asked if a single action movement could be given with the engine.

Mr. Joy replied that the principle of the engine applied equally to working single action, but there would be a waste of water and of power in that case.

Mr. Henry Maudslay said he had often thought what a great waste of the water power passing through houses was continually going on in the regular supply of water under pressure, and how great a variety of useful applications of this power might be made even without increasing the cost or consumption. The difficulty was to meet with an apparatus suitable for the purpose, and he was greatly pleased with the engine now described, as an excellent plan for accomplishing this desirable object, and was glad of the introduction of an apparatus which appeared so completely to have got over the practical difficulties.

The Chairman thought the engine was very well contrived, and would prove of particular advantage in many cases in which steam power could not be employed; the range of its application would be very wide, where boilers were objectionable from risk of fire or from the inconvenience of dust and steam amongst the work as well as from the space occupied by them. The water engine would certainly be very convenient from its compactness and simplicity and the complete safety and control over the power which it afforded.

He proposed a vote of thanks to Mr. Joy for his paper, which was passed.

The following Paper, by Mr. Charles Beyer, of Manchester, was then read :—

ON BALANCING THE VALVES OF STEAM ENGINES.

That a perfect equilibrium or balanced slide valve for the steam engine is now a desideratum need not be urged, seeing how many plans and schemes have been brought forward from time to time for the accomplishment of that object.

The large D valve as ordinarily adapted to 74 inch cylinders is shown in Figs. 1 and 2, Plate 130, the packing A being introduced at the back of the valve and kept up to it by means of the packing blocks B and the screws C. This arrangement cannot produce an equilibrium of pressure, as the opposite sides of the valve do not at all correspond with each other; and it will be easily seen that in every change in the position of the valve there is also a change in the effect of the pressure, which acts first in one direction and then in another and continually changes in amount. For instance, when the valve is drawn back to admit steam to the cylinder, the full pressure of the steam is directed against that portion of the packing which is directly opposite the port; and when the valve is drawn over and covers the port, that portion of the packing is subjected to the pressure in the cylinder acting against the face of the valve, as in the position shown in the drawing; and when the face of the valve is drawn beyond the packing, then the steam in the steam chest presses the face of the valve against the cylinder, these changes taking place continuously during each stroke of the valve.

The power required to move such valves in large engines, in starting or reversing the engines, is so great that the ordinary mode of handing was seen to be impracticable; it was therefore determined that the power of steam should be employed by attaching a small engine to each set of valves, so that the engineer was only required to move the valve of the small engine, instead of a dozen men or more being necessary to move the great D valve by the ordinary starting handle. But although the power of each of these small engines was equal to a force of upwards of 2 tons acting upon the great D valves, yet when they were fresh packed that power was not sufficient to move them, and in consequence the starting handles could not be entirely dispensed with; more especially as it was found in practice

that it was not safe to hand them by these small engines alone, but rather to apply a smaller steam power and make up the deficiency by the men at the starting handle; nevertheless, even with these imperfections, such an arrangement was considered a great improvement.

A parallel equilibrium valve has been substituted by Mr. Wilson of Patricroft to obviate these objections, longitudinal and transverse sections of which are shown in Figs. 3 and 4. The D valve just described is one of a pair, and this is also one of a pair, the steam being admitted either in between the valves or at the outer ends. D is the cylinder face with the port E, FF the back balance plate with the balance recess G opposite the port E. The valve is made with an opening H through from face to face, for keeping up a communication between the port E and the recess G when both are covered by the valve faces, by which means an equal pressure in the recess and the cylinder port is constantly preserved. I I is a packing on both sides of the valve to prevent the steam passing from one end of the valve to the other except by the port and opposite recess; and as the surface on the back plate is exactly equal to the surface on the cylinder face, and the recess equal to the port, and the opposite sides of the valve equal to each other, as also the packings on each side of the valve, it will be seen that all the opposite surfaces being equal a perfect equilibrium is maintained under any pressure and in all positions.

As this simple form of equilibrium or balanced slide valve overcomes all the difficulties before named, the application of it to marine engines would not only effect a saving of power and a consequent saving of wear and tear of the valves and valve gear, but at the same time the most complete control over even the largest engines would be obtained, and thereby the risk of accident to steam vessels resulting from want of that control would be avoided.

Figs. 5 and 6 show transverse and longitudinal sections of a circular balanced valve on the same principle, applied by Mr. Wilson to winding engines, where perfect control is of so much importance. This valve like the last described has the opposite surfaces equal, and the balance recesses opposite the ports also equal in area to the opposite ports; the valve is slightly tapered in order to obtain a perfect fit in the valve box, and is prevented from jamming by the tempering screw at the back end.

The steam passes through the casing to both ends of the valve and thence into the interior, through each side of which alternately it is admitted to the ports as in an ordinary short slide; and from the construction of the valve a perfect equilibrium is maintained.

This valve has been also applied to the steam hammer with the most perfect success, as shown in Fig. 13, Plate 132. So light is the friction upon these valves, and equally small the power to move them, that although many of them have been at work upwards of 3 years none of them have shown any tendency to wear after the first few days of being in action, and many of them are working with the same adjustment as at first, not having required any alteration since they were first started. This is much more than was expected, and it was feared that the valve might wear oval if placed horizontal; but on examining several valves after being 2 years at work night and day under a pressure of 60 lbs., it was found that the top side of the valve and box was as highly polished as the bottom side, not with a white metallic polish, but black like that of a plate glass mirror; which appears the best proof that no sensible wear was going on, and that the surfaces were really not touching when working, but were kept asunder all round by a thin film of moisture from the steam, acting as a lubrication, preventing contact and thereby preventing wear.

An application of the same principle of valve to locomotive and other engines is shown in Figs. 7 and 8, Plate 131, which are transverse and longitudinal sections of a parallel equilibrium slide valve, with a loose back balance plate, by means of which the valve is allowed to leave the face of the ports when water gets into the cylinder. This valve is the same in principle as the one shown in Figs. 3 and 4, except that it requires no packing. It is equally adapted for two or three ports as the case may be. In this, as in the other valves, the opposite areas are all equal, which is the particular feature of this kind of valve, whereby alone a perfect equilibrium is obtained.

Figs. 9 and 10 are sections of the same valve without the loose plate, the cover of the steam chest then forming the back plate, with surfaces and balance recesses the same as with the loose plate.

Fig. 11 is a section of a duplex valve, to act as an expansion or cut off valve, at the same time serving as an ordinary steam valve, having all the advantages of a broad face for cutting off the steam at an early part of the stroke, whilst the exhaust does not require to be opened or shut

any sooner than with a valve of ordinary lap. This is effected by the outside frame acting as the cut-off and admission valve, and the inside frame as the exhaust valve; the outside frame having a longer travel than the inside one, the difference being equal to the difference in the length of the frame.

Fig. 12 is a section of the valve and steam chest of an ordinary locomotive engine; and by comparing this with the other valves it will be seen what a large surface is exposed to the pressure of steam on the one side without an equal counterpoise or balance on the other; this circumstance causes the wear and tear of this kind of valve and valve gear to be very great, and a considerable amount of force is consequently required to keep it in motion, which in some cases is more than one tenth of the whole power of the engine.

Mr. Wilson observed that the principal point in the balancing of the slide valves was that it depended as much on having an equal recess at the back of the valve, corresponding with the opening of the port, as on having equal surfaces for the pressure to act upon in both directions; and that was a point that had not been generally attended to. In the first forms of balanced valve that had been described, when the valve shut over the port, the communication was still kept up between the port and the recess at the back of the valve, so that the valve was always in equilibrium. In the locomotive valve shown, a provision had to be made for the escape of water from the cylinder in case of priming, which was effected by the back plate giving way at the moment to the extra pressure and allowing the valve to rise from the face of the ports like an ordinary slide valve, there being nothing but the steam to keep it down to the face. In the steam hammer the regular self-acting apparatus for moving the valve, although very ingenious, was found objectionable from its great complexity, and the balanced valve that had been described was worked entirely by a simple hand lever; this was now working at the Low Moor Iron Works very satisfactorily, and was found to be of great advantage, giving greater facility for changing the stroke of the hammer, causing no delay in the operation, and saving time with the work.

Mr. Henry Maudslay was much pleased with the action of the balanced valve in the steam hammer which he had seen at work at Low Moor; it was perfectly easy of management and worked quite efficiently; but it seemed to him that the work would depend on an experienced workman holding the handle, instead of a boy only directing the self-acting gear. In the latter case the boy was only told to wind the handle up or down to regulate the blows of the hammer; but in the other plan the man was required to use his judgment and care in moving the valve exactly to the distance required at each stroke. Supposing a piece of work under the hammer nearly finished, only light blows would be wanted, and the self-acting apparatus being once adjusted to give light blows no delay would occur from alteration of the gearing.

Mr. Pilkington had had three hammers working for some time with the balanced valves that had been described, and found their working was quite satisfactory and decidedly preferable to the self-acting gear. The result was that a boy at 10*d.* per day now drove the hammer better than a man at 4*s.* per day could do previously, since the blows could be so much more readily and quickly varied to suit the work, and lighter and quicker blows given at any time whenever desired without a moment's delay. With the aid of the alteration in the gearing, and the greater space for the work allowed by removal of the former platform required for the man working the gear, he was able to get work under the hammer more than a foot higher than before, and had recently forged under a 30 cwt. hammer a shaft nearly 5 tons weight and 18 feet by $8\frac{1}{2}$ inches. There was no difficulty in regulating the force of the blow with as great certainty as before, by putting a pin in any required hole of the guide for the hand lever, down to which the lever was pressed at each stroke, giving a constant quantity of steam for each stroke, whilst a lighter blow was given at any moment by stopping the lever short of the pin.

Mr. Morrison said it had been generally considered that self-acting gear was superior for steam hammers, but he had been much pleased with the action of the balanced valve worked by hand, which he had seen at Low Moor; he had since applied a balanced valve of somewhat different construction to his own hammer, and was satisfied that such a mode of working was preferable to self-acting gear. The time lost in screwing up the gear to adjust it to a different blow was important when a heavy forging was under the hammer, and the

constant weekly expense of oiling and repairing the self-acting gear made a serious amount; there was also a saving in the cost of wages for working, as he had now only a labourer working the hammer at 16*s.* per week instead of a man at 24*s.* per week previously. The hammer could now be worked almost up to the stuffing box, giving a great advantage in getting command of the full length of stroke; he was sure that wherever the balanced valve was adopted, it would be adhered to in preference to self-acting gear.

Mr. Wilson observed that the use of the balanced valves in winding engines had been also found a great advantage in economy and convenience; in some cases of large winding engines where he had applied them a saving of £120 a year had been found to be effected in each engine, from the greater wear and tear and the greater expense of working the engines with the old valves. Two or three men were required previously to hand the engine with safety, causing increased risk of accident with a deep pit, from the difficulty of managing the engine promptly and readily; but with the balanced valves that was now done with ease by one man.

Mr. Tomlinson asked how it was arranged to make up for the wear of the valve from the back plate, in the case of the locomotive slide valve; there did not appear to be any provision for keeping the back steam tight after wear had taken place.

Mr. Wilson replied that he had found the wear was so slight that the elasticity of the plate was sufficient to compensate for it, by the deflection of the plate under the pressure between the supporting sides; for no beam however strong would support a load without bending, and this plate was found to bend sufficiently for the purpose of allowing for the wearing of the surface on which it rested. The back plate was surfaced in a slightly bent position by being cramped into that position while surfacing, and it seemed that then both the valve face and the back plate continued steam tight. The wear of the valve was reduced to a very small amount by balancing the pressure, as it was the pressure only combined with the motion that produced friction; and when the friction was so much reduced, the rubbing surfaces got a fine polished face and continued working for a long time with scarcely any perceptible wear. In the case of vertical valves the wear was still less, the weight of the valve itself being removed.

Mr. PILKINGTON said that at a winding engine working a short pit at Incehall Colliery, the eccentrics had actually been taken off and the engine was worked entirely by hand, having balanced valves working very easily; the engine was thus under the most complete control as to speed, stopping, and starting, and was found to work quite satisfactorily.

The CHAIRMAN observed that the general principle of balanced valves was undoubtedly good, and the plan described in the paper seemed a good and successful mode of effecting the object. There were however several cases, such as locomotive engines, where simplicity of construction was of so much importance as to add materially to the difficulty of getting an entirely satisfactory balanced valve.

He proposed a vote of thanks to Mr. Wilson, which was passed.

The following Paper, by Mr. William G. Craig, of Manchester, was then read:—

DESCRIPTION OF AN APPARATUS FOR ECONOMISING FUEL.

The object of the apparatus forming the subject of the present paper, which is the invention of Mr. Green of Wakefield, is to economise fuel and increase the evaporative power of the boiler. The necessity for such an apparatus is founded on the assumption that the heat from the furnaces of steam boilers cannot be effectually or sufficiently absorbed by an ordinary boiler surface; for in all cases it is found that when the temperature of the gases becomes reduced down to a certain point, this point varying slightly with various descriptions of coal, there commences a formation of soot, which being a bad conductor of heat renders any further exposed boiler surface of little or no service. It is at this stage that a considerable amount of heat still remains in the gases, and in that case there is no alternative but to allow it uselessly to escape at the chimney.

The apparatus now to be described is for the purpose of effectually absorbing and rendering practically useful this surplus heat. It is shown in Plate 133, and consists of a series of upright pipes or tubes AA introduced between the boilers BB and the chimney flue C, through which the feed water is made to pass on its way to the boilers, and is there heated to above the boiling point, and a considerable quantity of steam is also generated before the water enters the boiler. The idea on which its practicability is founded is a very obvious one, that of placing a number of pipes in the flues; but the practical solution was not so easy, as the great defect yet to be overcome was the formation of a coating of soot on the pipes, a defect which has impeded previous attempts of a similar character. This difficulty is entirely obviated by an apparatus of scrapers or cleaners, which consist of connected rings DD made to encircle the pipes; these are constantly but slowly kept in motion by means of the chains and pulleys EE driven by a belt F from the engine; the scrapers traversing the whole length of the pipes, and thus preventing any accumulation of soot on their outer surfaces, and facilitating the transmission of the heat to the feed water.

The temperature of the feed water as supplied to the boiler in this arrangement varies according to the heat in the flues and the quantity of heating surface exposed by the pipes. It is found that when the waste heat from the boiler escapes even as low as from 400° to 500° the feed water can be heated to an average of 225°, the temperature of the gases after leaving the heating pipes being reduced to about 250°. To produce this effect it is generally found that about 10 square feet of heating surface in the pipes is required for each horse power.

At Messrs. Thomas Hoyle and Son's Print Works in Manchester, where the above apparatus has been applied to eight large boilers, the heat of the water entering the apparatus is 40°, and this is raised to an average temperature of 249°. This apparatus consists of 200 pipes, 4 inches diameter and 9 feet long, presenting a heating surface of 2000 square feet.

At the Oxford Road Mills of Messrs. Cook the feed water from the hot well of the engine enters the apparatus at a temperature of 130° and is there raised to 250° and 275°. The apparatus consists in this case of 160 pipes, presenting about 1700 square feet of heating surface, and it is applied to multitubular boilers.

This apparatus is now extensively adopted in this country and also on the continent, and has been applied to most varieties of boiler, but more particularly to double furnace and multitubular boilers. It is now in operation on boilers amounting in the aggregate to about 25,000 horse power. The results obtained at several of the largest cotton mills, print works, paper mills, &c., where this apparatus has been at work for 4 and 5 years, show a saving to have been effected by it in the consumption of coal of from 17 to 25 per cent., varying with the different descriptions of boilers, situations, &c. An important point in this apparatus is that it will last longer than the boiler, as it is not liable to get out of repair; and it can be applied to new or old boilers of any description without stopping the works.

Mr. Craig observed that he had been much pleased with the ingenuity and completeness of the apparatus, and had been informed by two of those who had had the apparatus at work a considerable time with their boilers, Messrs. Cook and Birley, that the result was very favourable and satisfactory as to the economy obtained from the apparatus and as to its keeping in order, the temperature of the feed water being found to average about 260°. The apparatus appeared to him a very complete mode of carrying out the desirable object of preventing waste of heat by taking it up in the feed water, which had been previously done less completely in a variety of ways. The only difficulty he felt was that when leakage of the pipes took place, the soot would have a tendency to get hardened and stop the motion of the scraper; but this he thought might be completely obviated by tapering the pipes a little smaller at top and bottom to allow the scraper to pass over and clear itself at every stroke. The high temperature obtained in the feed water showed that an important economy of fuel was effected by the apparatus, all the heat below 300° at least in the flue being unavoidably lost in ordinary working, as it could not be taken up by the boiler, the water in the boiler being already near that temperature, and the only way of saving it was by taking it up in the cold feed water; he thought that a saving of at least 12 to 15 per cent. was effected in the consumption of fuel.

Mr. Leese had had the apparatus 7 or 8 years on the boilers at the India and Mersey Mills, Stockport, where it was applied to 2 sets of 6 boilers; he found it decidedly economical and successful, and had been completely satisfied with the results. He considered that a saving of as much as £500 per year was effected by the use of the apparatus in the cost of fuel in his boilers; the present average consumption was from 130 to 135 tons per week, and the consumption was found to be from 155 to 160 tons per week on an average of three months when the apparatus was stopped; the boilers were high pressure, and there could be little difference in the work done in the two cases, which was driving a cotton mill.

The Chairman asked what had been the cost of keeping the apparatus in repair, and whether it was found to cause trouble by leaking in the pipes or getting out of order, and requiring stoppage of the boilers for repairs; it was very important for any such apparatus not to be liable to such occurrences, and any moving machinery inside the flue would at first appear to involve a risk in that respect.

Mr. LEESE replied that the scrapers first applied got a little out of order and gave some trouble, but that was remedied by experience, and the apparatus had ever since worked completely well, the whole repairs being very insignificant. The examination and cleansing of the apparatus was readily done by shutting it off entirely from the course of the boiler flue by means of a damper, so that the draught went direct into the chimney, and any repairs could be effected without at all delaying or interfering with the working of the boilers.

The CHAIRMAN asked what extent of deposit was found to take place in the apparatus; he thought that at the high temperature to which the water was raised in the pipes some choking up with deposit might be feared.

Mr. LEESE said there had been very little deposit in the apparatus, as the water was only heated in the pipes whilst being passed through to feed the boiler, and very little evaporation could take place in them, the deposit being thrown down only from such water as was actually boiled off.

Mr. HENRY MAUDSLAY enquired whether the apparatus being placed in the flue, obstructing the passage and cooling the temperature, was found materially to interfere with the draught and require any higher chimney.

Mr. LEESE replied that no difficulty of that kind had been experienced, and not any alteration of the chimney had been found requisite after putting up the apparatus; there was however a material diminution in the quantity of fuel that had to be burnt in the same time.

The CHAIRMAN thought the plan appeared one of considerable value, and was a bold attempt to carry out the principle of heating the feed water with the waste flue heat, by the addition of mechanical apparatus to aid in carrying it out more completely.

He proposed a vote of thanks to Mr. Craig for his paper, which was passed.

The CHAIRMAN said the business of the meeting was concluded, and he was sure the result of the present Manchester Meeting of the Institution was very gratifying to all the Members, from the practical usefulness and interest of the Papers that had been read and the discussions upon them, and the opportunity that had been afforded them for seeing so many important works in the neighbourhood, and the interesting collection of engineering models, &c., that had been prepared on the occasion. They were certainly under a great debt of gratitude to their friends for the great trouble they had taken and the excellent arrangements they had made, in consequence of which this Manchester Meeting had undoubtedly proved a great success.

The Meeting then terminated.

In the evening a large party of the Members and their friends dined together at the Art Treasures Exhibition in celebration of the Meeting of the Institution in Manchester.

RAILWAY CARRIAGES.

Fig. 1. *Old Train.*

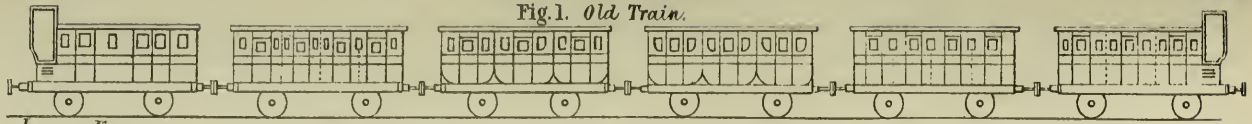


Fig. 2. *New Train.*

Fig. 3. *New Carriage with Luggage Compartments.*

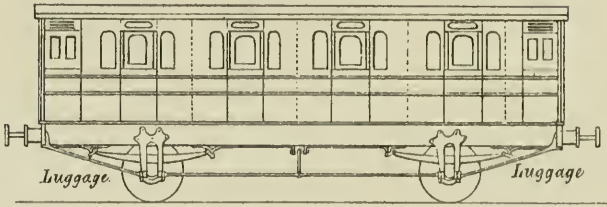


Fig. 7. *Third Class Carriage.*

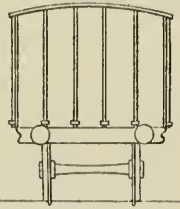


Fig. 8.

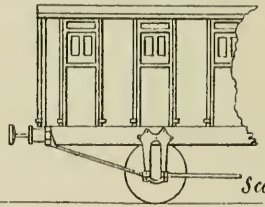


Fig. 4. *Trussing of Frame.*

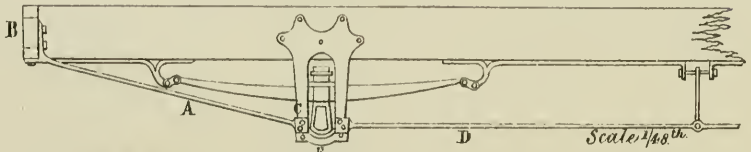


Fig. 5.

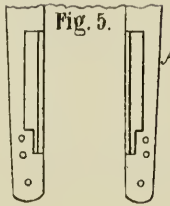
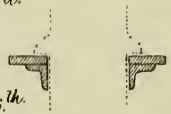


Fig. 6.



(Proceedings Inst. M.E. 1857. Page 150.)

Plate 126.

Single Furnace.

Fig. 1. Elevation.

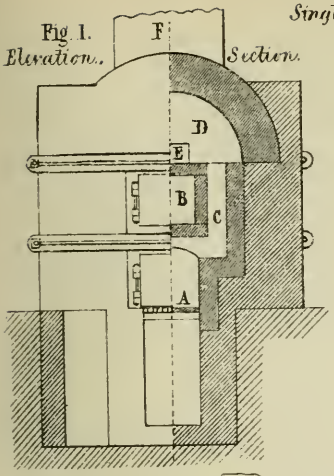


Fig. 2. Longitudinal Section.

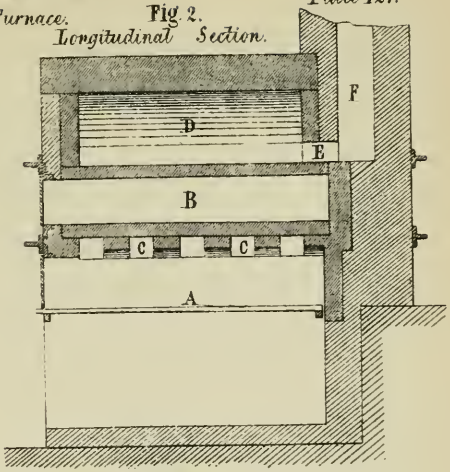


Fig. 3. Double Furnace.

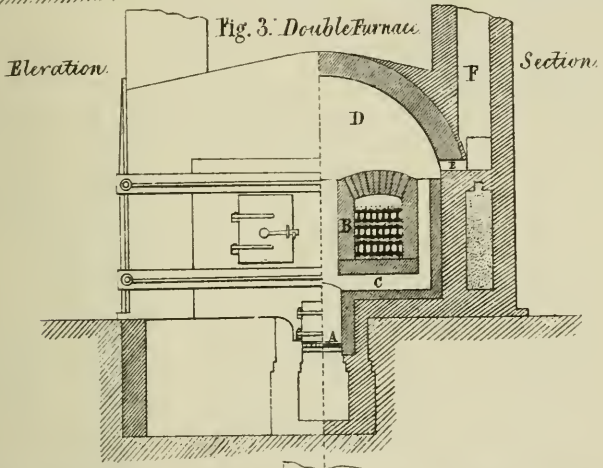
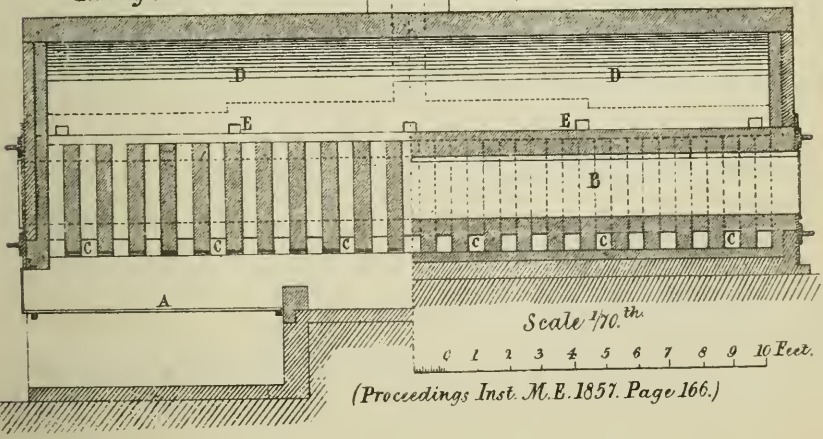


Fig. 4. Longitudinal Section Through centre of Furnace.

F

of Double Furnace. Through centre of Oven.



(Proceedings Inst. M.E. 1857. Page 166.)

PISTON WATER METER.

Chadwick and Frosts Meter.

Fig. 1.
Longitudinal Section.

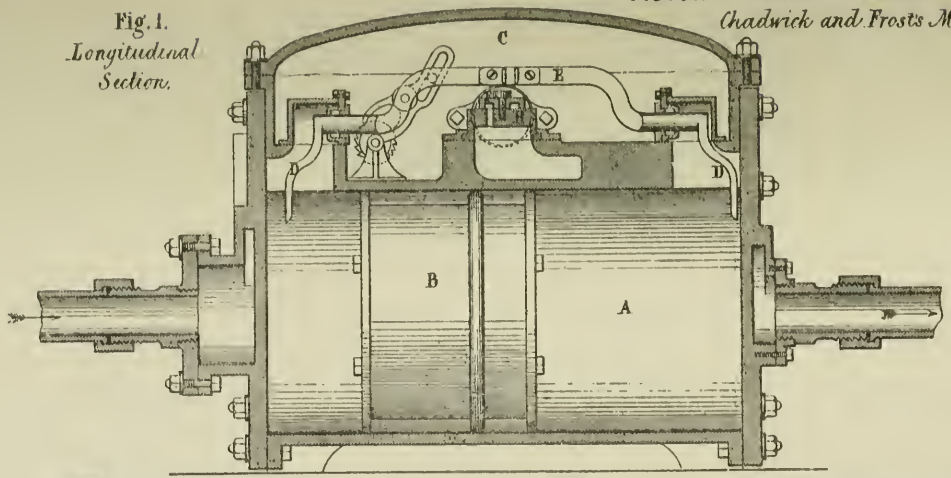


Fig. 2.
Transverse Section.

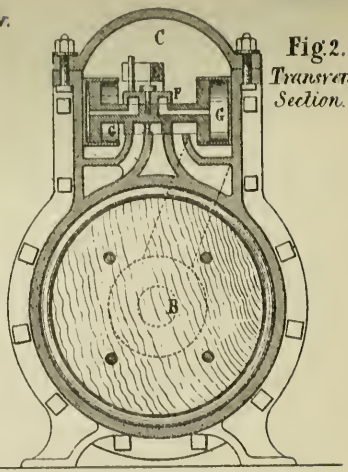


Fig 3. *Plan with cover removed.*

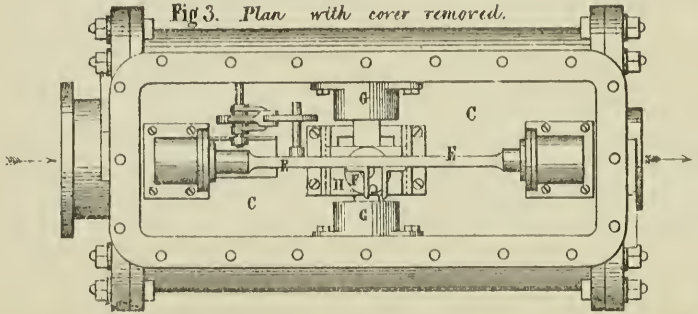
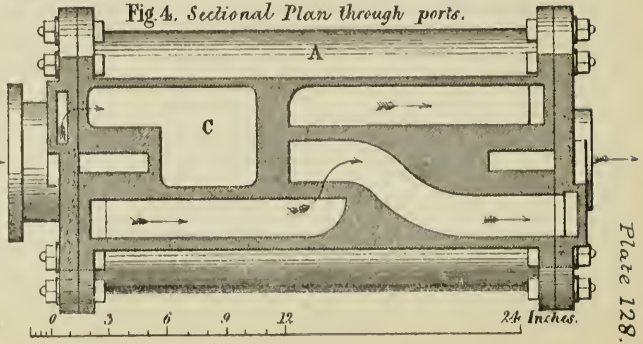


Fig 4. *Sectional Plan through ports.*



(Proceedings Inst M.E. 1857 Page 175.)

Scale 1/10th

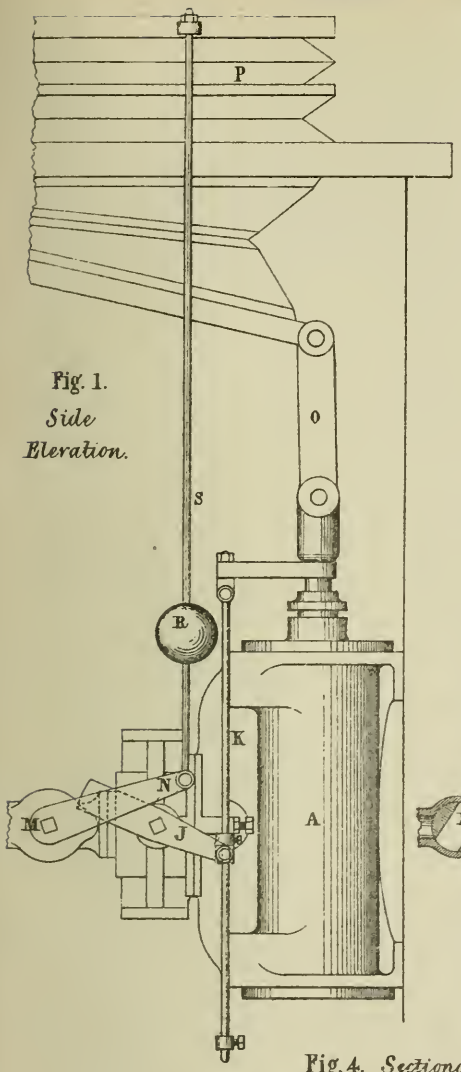


Fig. 1.
Side Elevation.

Fig. 3.
Vertical Section through Valve Chest.

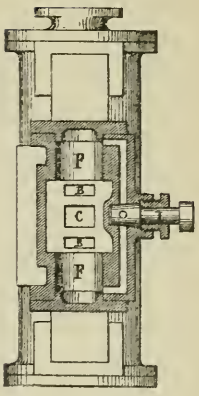


Fig. 2.
Vertical Section.

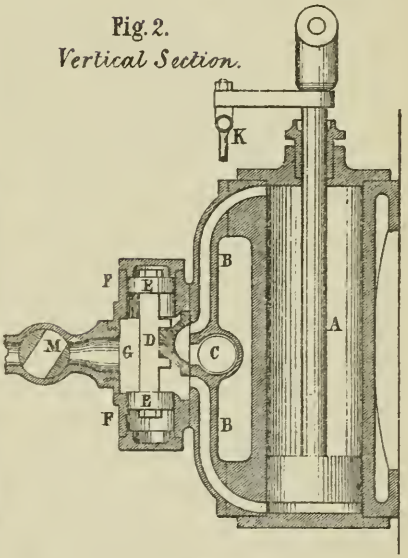
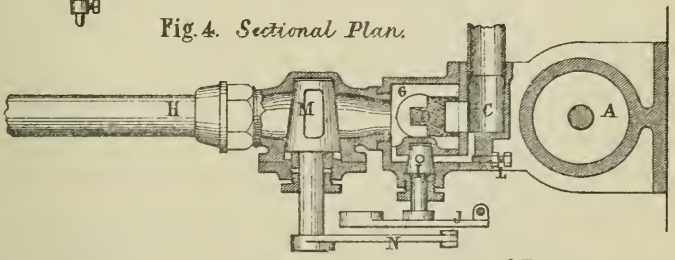


Fig. 4. *Sectional Plan.*



Scale 1/12th. 1 2 Feet.

(Proceedings Inst. M.E. 1857. Page 184.)

Fig. 1. *Ordinary* D *Valve.* Fig. 2.

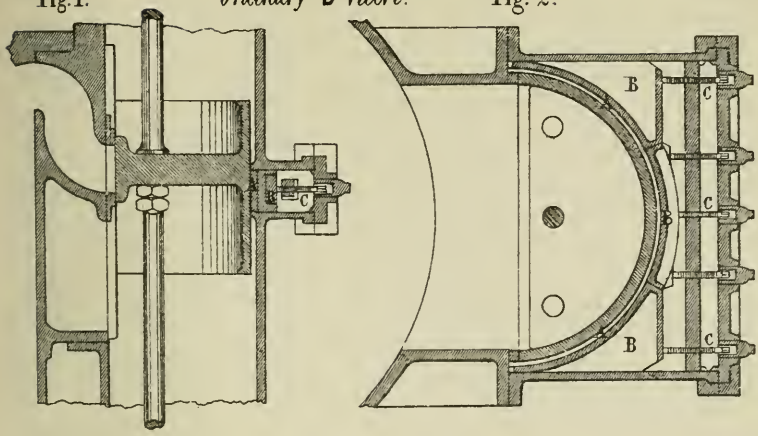


Fig. 3. *Parallel Balanced Valve.* Fig. 4.

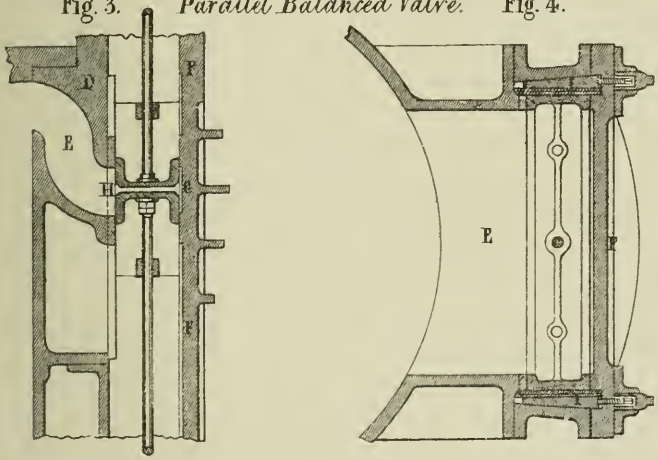
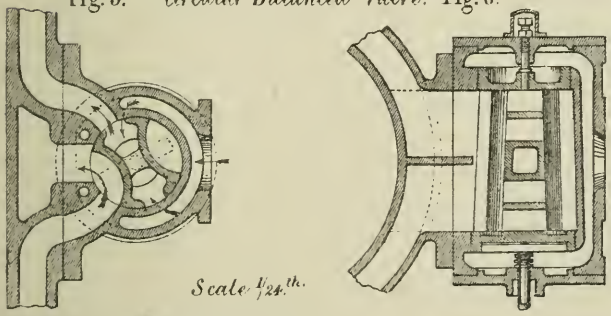


Fig. 5. *Circular Balanced Valve.* Fig. 6.



Scale 1/24th.

(Proceedings Inst. M. E. 1857. Page 189.)

Fig. 7.

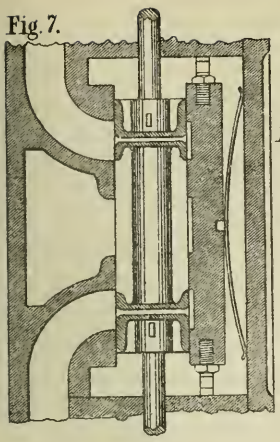
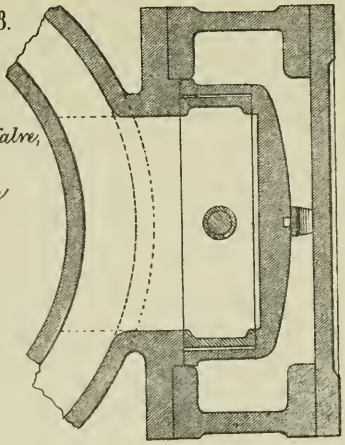


Fig. 8.



Parallel Balanced Valve, for Locomotive Engines.

Fig. 9.

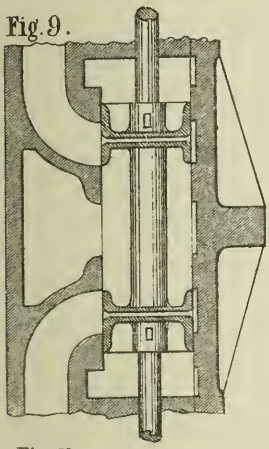
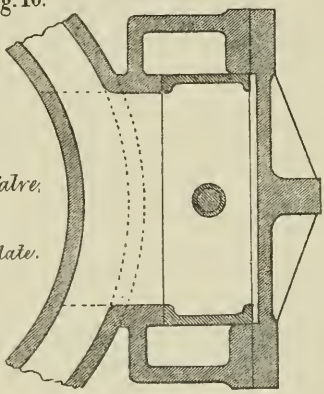
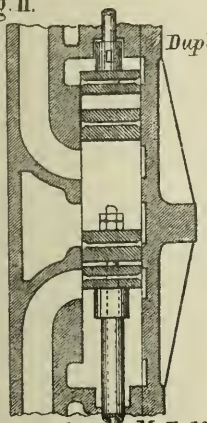


Fig. 10.



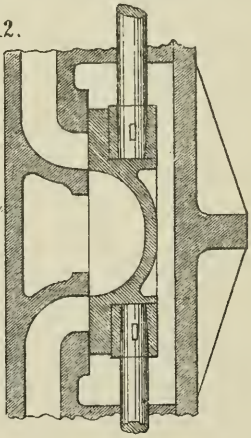
Parallel Balanced Valve, without loose back plate.

Fig. 11.



Duplex Balanced Valve.

Fig. 12.



Ordinary Locomotive Valve.

Scale 1/8th.

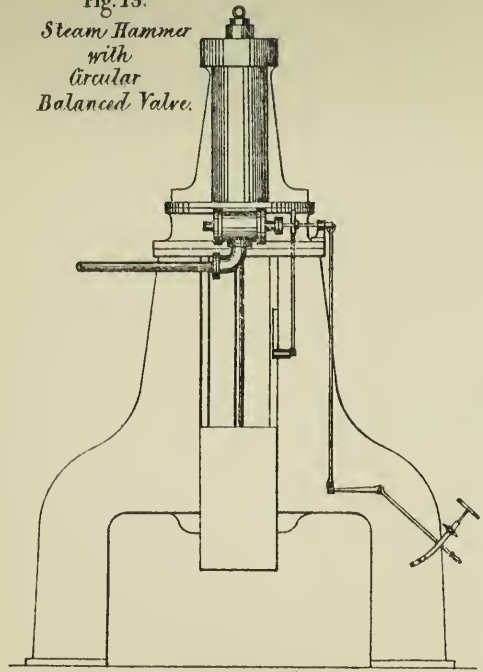
(Proceedings Inst. M. E. 1857. Page 191)

BALANCED STEAM VALVES.

SAFETY ESCAPE PIPE.

Plate 132.

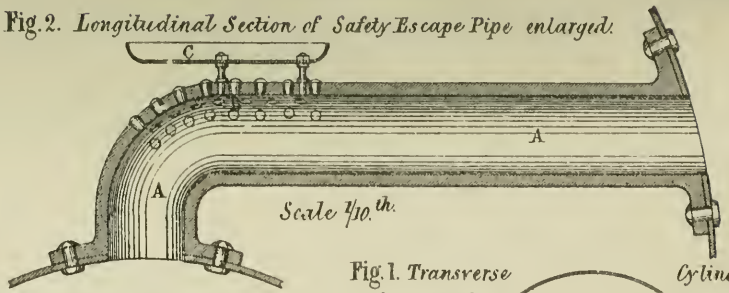
Fig. 13.
Steam Hammer with Circular Balanced Valve.



Scale 1/60th.

(Proceedings Inst. M.E. 1857. Page 191)

Fig. 2. *Longitudinal Section of Safety Escape Pipe enlarged.*



Scale 1/10th.

Fig. 3. *Cylindrical Boiler with internal fireplace.*

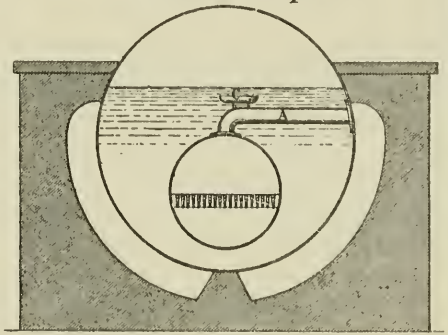
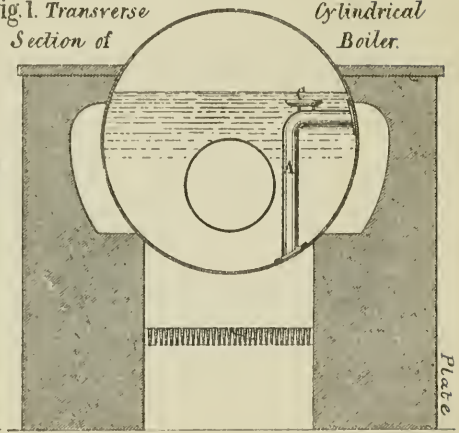


Fig. 1. *Transverse Section of Cylindrical Boiler.*



Scale 1/60th.

0 1 2 3 4 5 6 7 8 9 10 Feet.

Plate 132

FUEL ECONOMISER.

Plate 133.

Fig.2. *Transverse Section.*

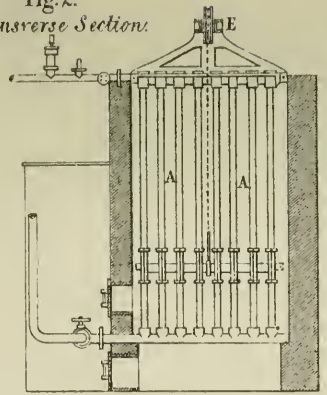


Fig.1. *Longitudinal Section.*

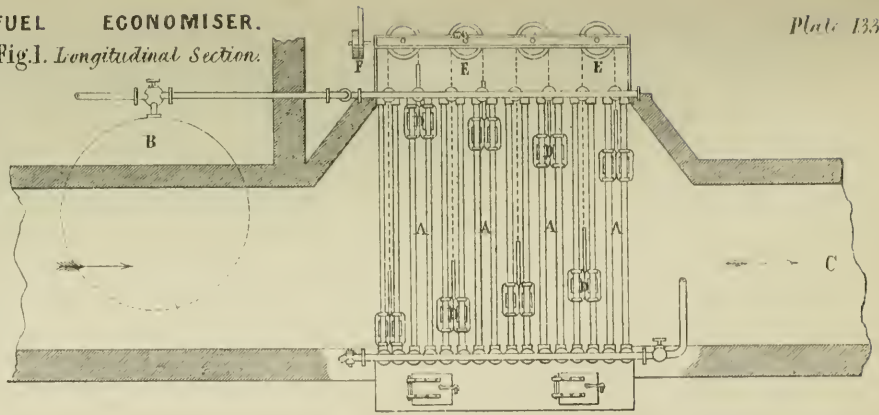


Fig.3. *Sectional Plan.*

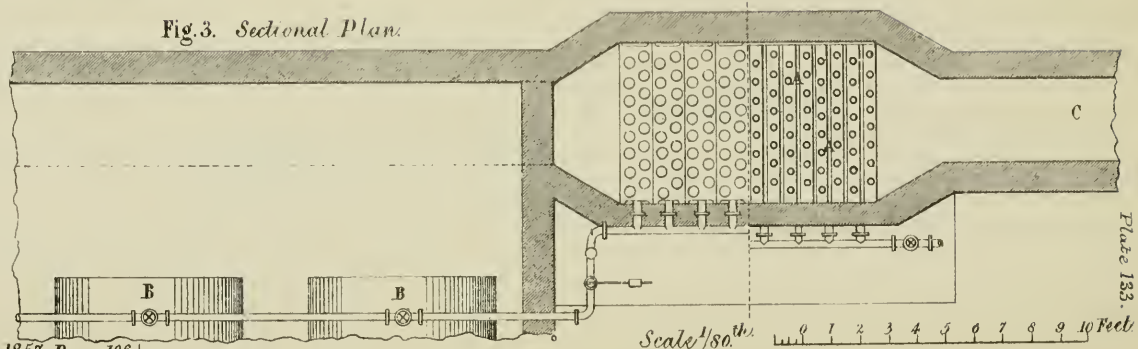


Plate 133.

(Proceedings Inst. M. E. 1857. Page 196.)

Fig 1. *Front Elevation.*

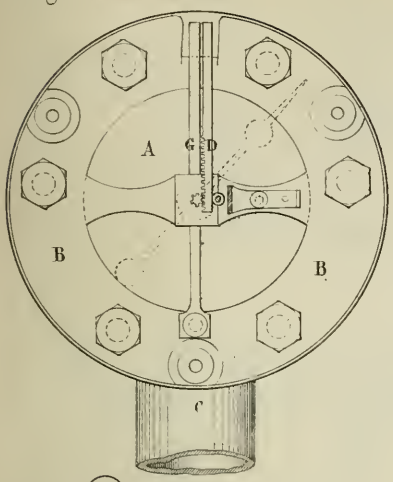
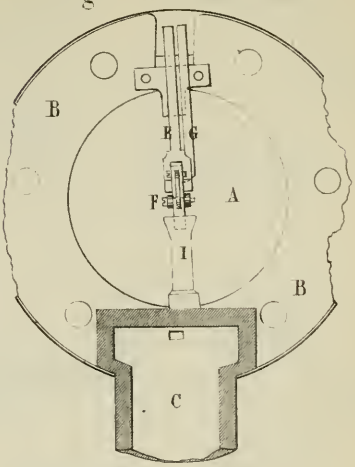


Fig. 2. *Back Elevation*



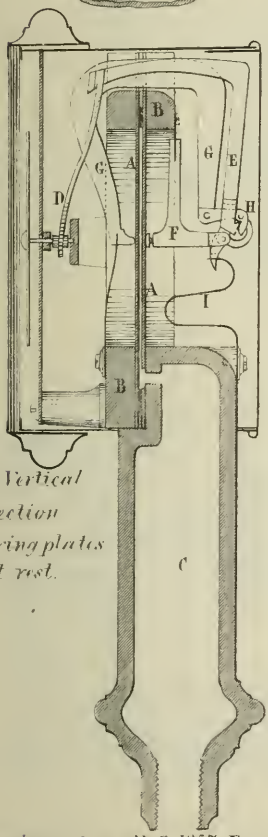


Fig 3. *Vertical Section showing plates at rest.*

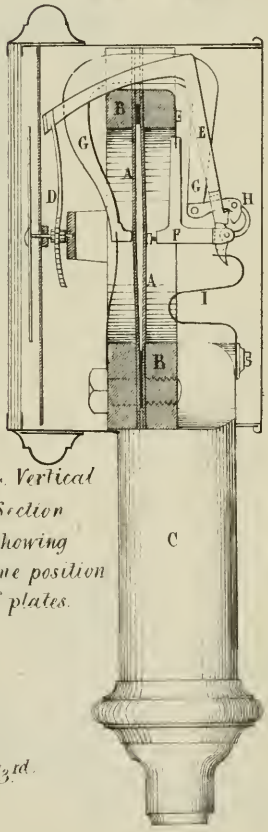


Fig. 4. *Vertical Section showing extreme position of plates.*

Scale 1/3rd.

(Proceedings Inst. M. E. 1857 Page 204.)

SAFETY VALVES.

Plate 135.

Fig. 1.

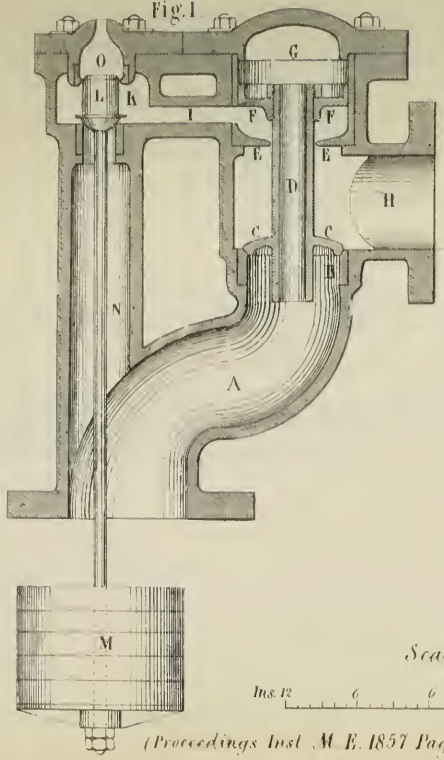


Fig. 2.

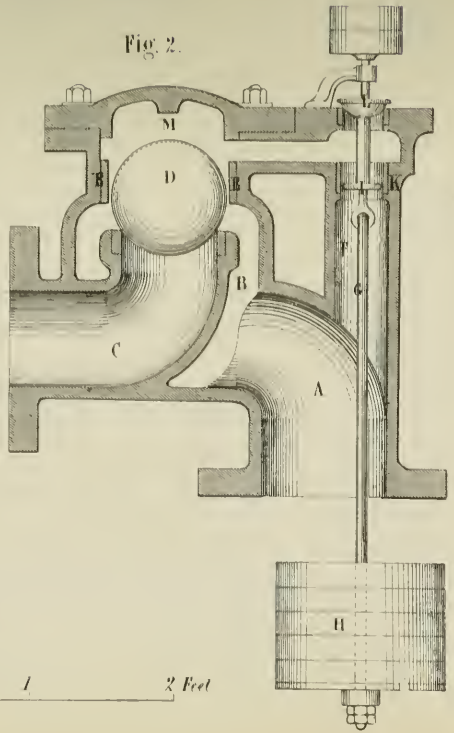
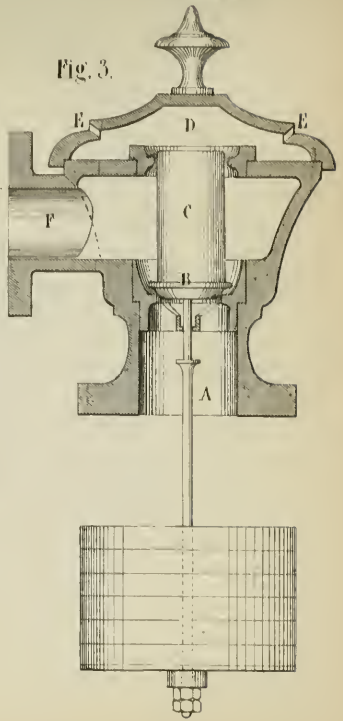


Fig. 3.

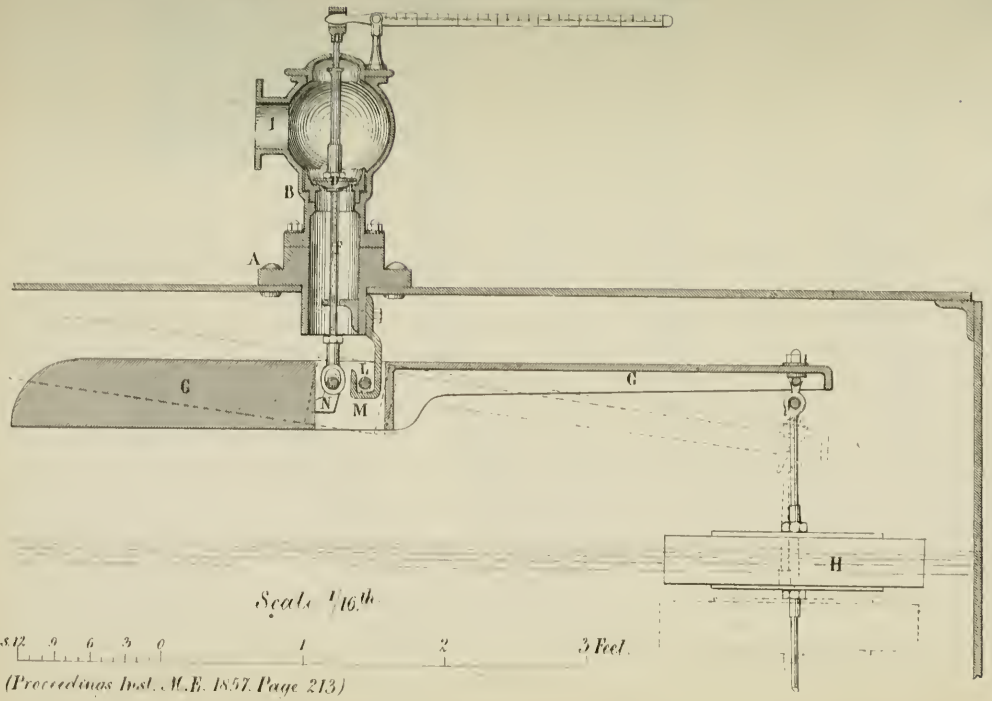


Scale 1/16th.

Ins. 12 6 0 1 2 Feet

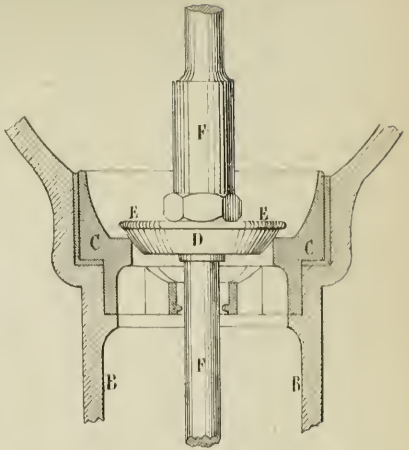
(Proceedings Inst. M. E. 1857 Page 211)

Fig. 4. *Safety Valve for Steam Pressure and Low Water.*



(*Proceedings Inst. M.E. 1857. Page 213*)

Fig. 5. *Enlarged View of Valve*



Scale 1/4th

Fig. 1. *Wagon Bearing Spring with rolled eyes.*

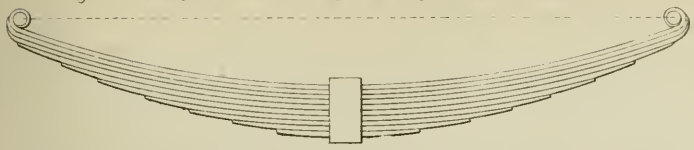


Fig. 2. *Wagon Bearing Spring with thickened ends.*

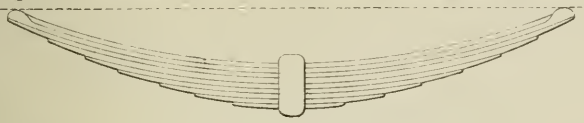


Fig. 5. *Wagon Bearing Spring with plates separated at centre.*

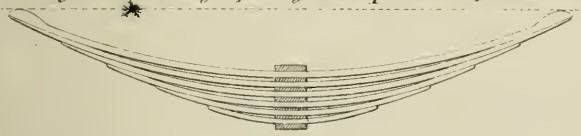
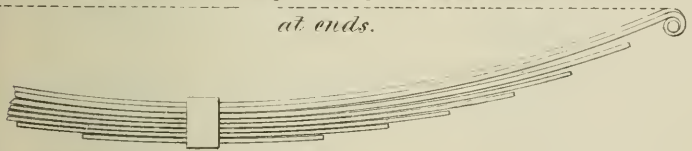


Fig. 6. *Carriage Bearing Tension Spring.*

Fig. 7. *Carriage Bearing Spring with plates separated at ends.*



Scale 1/12th. Ins. 12 9 6 3 0 1 2 Feet

Fig. 3. *Transverse Section.*

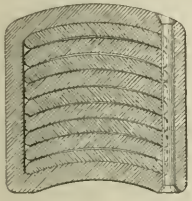
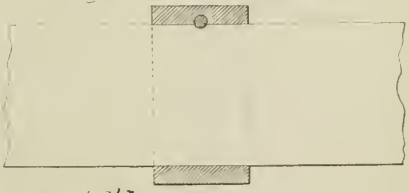


Fig. 4. *Sectional Plan.*



Scale 1/4th.

(Proceedings Inst. M.E. 1857. Page 220.)

PROCEEDINGS.

August 5, 1857.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 5th August, 1857; William Fairbairn, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting, held in Manchester, were read and confirmed.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for that purpose, and the following New Members were duly elected :—

MEMBERS.

James Lloyd Ashbury,	Manchester.
Edward Taylor Bellhouse,	Manchester.
Richard Chrimes,	Rotherham.
Francis James Cortazzi,	Doncaster.
John Horridge Deane,	Barcelona.
Charles De Bergue,	Manchester.
Robert Francis Fairlie,	London.
James Fletcher,	Manchester.
William Hall,	Tipton.
Edward Charles Healey,	London.
William Jenkins,	Manchester.
James Clarkson Kay,	Bury.
Sylvester Lees,	Bury.
George March,	Leeds.

B. H. Martindale, R.E., . .	Sydney.
George Rennie, . . .	London.
William Routledge, . .	Manchester.
Thomas Snowdon, . . .	Middlesboro'-on-Tees.
George Trickett, . . .	Manchester.
Frank W. S. West, . .	Birmingham.
John Wilson, ...	Westbromwich.
Robert Wilson, . . .	Patricroft.

The Chairman remarked that it was highly satisfactory and encouraging to see the valuable addition to the Institution that was taking place by the rapid increase in the number of members, which augured well for its prosperity and the extension of its usefulness.

He observed that the last meeting of the Institution had been held in Manchester, and had proved very successful and interesting, from the number of valuable papers read on the occasion, and the different objects of interest that had been seen, as well as the visit to the Art Treasures Exhibition. The large meeting held in the previous year at Glasgow had also been highly successful; and these meetings had been of such a character as to lead the Council to continue them every year in other large manufacturing towns throughout the kingdom, such as Newcastle, Leeds, Dublin, &c., and probably in London; he hoped the members would do their best to promote so desirable an object.

The Chairman had much pleasure in announcing that a valuable and very acceptable donation of engineering books had been presented to the Institution by one of the Vice-Presidents, Mr. Henry Maudslay, for the special purpose of establishing a Library of Reference; this was an object which he was very anxious to see carried out, and to which he had himself called the attention of the members on former occasions when President of the Institution, since it was of great importance that they should have a collection of good books at command in the Library of the Institution.

He was glad to see so excellent an example set by Mr. Maudslay, and trusted that it would be followed generally by the members, by the presentation of books or donations towards the purchase of books for the Library; such contributions would prove highly acceptable and important to the Institution, and if all were to help a little the object might soon be satisfactorily accomplished. In order to aid the members in this matter, a catalogue would be prepared by the Secretary and sent round to them, in order to show what was now wanting in the Library and to avoid having duplicates. He proposed a cordial vote of thanks to Mr. Maudslay for his handsome donation, which was passed.

The following Paper, by Mr. John Inshaw, of Birmingham, was then read :—

DESCRIPTION OF AN IMPROVED PRESSURE GAUGE.

The pressure gauge forming the subject of this paper is shown in Figs. 1 to 4, Plate 134.

Fig. 1 is a front elevation of the gauge, with the dial plate removed. Fig. 2 is a back elevation, with the casing removed and the air chamber at the bottom in section. Fig. 3 is a vertical transverse section through the centre, showing the position of the parts when at rest; and Fig. 4 shows their extreme position under pressure.

The gauge consists of two flat steel pressure plates or discs AA, placed between two circular cast iron frames or flanges BB, the pressure being admitted between the plates through the air chamber C cast upon the back frame B. The deflection or bulging of the plates produced by the pressure is communicated to the index by means of a toothed curved rack D fastened to the arm or lever E, gearing into a small pinion on the spindle of the index. The lever E works on a steel pin screwed in the suspended centre piece F, which is kept in contact with the centre of the disc at the back of the gauge. Another bent arm G is kept in contact with the centre of the front disc, and passes round to the back of the gauge, being made with a hooked extremity H, by which it presses on the back of the lever E. The end of the arm G is kept at the proper distance from the pin on which the lever E works by means of a small curved radial link or distance piece. A small tail spring I is fixed to the frame B, bearing on the end of the lever E, which brings the lever back when the pressure is removed, and keeps both the centre bearing points always home against the discs.

The action of the gauge is as follows:—when the pressure is admitted to the air chamber C and the air between the discs, the discs are bulged or deflected outwards in opposite directions to each other; the front arm G is thus pushed outwards or towards the left hand, and its hooked extremity H pressing on the back of the lever E is drawn inwards towards the left, at the same time that the centre piece F at the back of the gauge is forced outwards to the right, carrying with it the end of the lever E. The lever E is thus deflected to a double extent, and a double range of action is obtained compared with a single disc; and compound leverage as required in single disc gauges is dispensed with, the friction consequent upon it being avoided.

In order to obtain a uniform graduation of the dial throughout all parts of the scale, the bearing extremity of the hooked end H of the arm G is made in a curved form, and bears upon an inclined plane on the back of the lever E. By this arrangement, when the discs deflect, the point of contact between the two gradually rolls along the incline nearer to the centre piece F on which the lever E works, thus altering the leverage, so that the motion of the lever and index corresponding to a given deflection of the discs is increased as the resistance of the pressure plates increases with increased deflection, causing the graduation of the dial to be uniform. The adjusting of these two bearing surfaces is effected after the gauge is made, by trial under pressure with a mercury column, by means of which the accuracy of the indications of the gauge is checked throughout the entire scale.

The suspended centre piece F at the back of the gauge and the arm G in front are attached to the frame by strips of thin watch-spring steel, which hold the two bearing points accurately and steadily in the centre of the discs, while they do not impede the deflection of the plates or the action of the arms; this construction reduces the friction and wear to a very insignificant amount. The centre piece F bearing on the back plate has a small screw in its bearing point, by which the index is readily adjusted to the zero of the scale when the gauge is put together.

The steel pressure plates or discs used in the gauge are hardened and tempered, and then planished and set perfectly flat, after which they do not set on being subjected to double the pressure to which the gauge is indexed. They are afterwards electroplated with copper or other incorrodible metal, which prevents them from becoming oxidised. The plates vary in thickness or strength according to the pressure they are required to indicate, from No. 8 or 9 wire gauge to No. 25 or 26 wire gauge, or from ·16 inch or about $\frac{1}{6}$ inch to ·02 inch or about $\frac{1}{50}$ inch thickness. They are firmly joined together by six screws round the edge, the centre part forming a cavity of $3\frac{1}{4}$ inches diameter and $\frac{1}{16}$ inch width. The joint round the circumference is made air tight by an india rubber packing ring, upon which the plates are screwed up tight, a narrow copper ring of $\frac{1}{16}$ inch thickness being also placed between the plates around the india rubber ring, which limits accurately the distance between the plates, and also prevents the india rubber from spreading outwards under the pressure of the tightening screws. The pressure is admitted between the plates through a small hole at the

bottom in the back plate, which opens into the air chamber C. The plates being gripped tight round the circumference are in a state of tension when deflected, which assists them in regaining their original shape without a tendency to set.

The pressure gauge now described is the result of long attention given by the writer to the subject, in consequence of having experienced imperfections in gauges of different constructions, which did not prove entirely satisfactory from various causes. An essential of a good pressure gauge is that it should not have any part that is liable to give way or wear out within a long period; also that no part should be subject to any change during that time affecting the indicatoin of the gauge by alteration in the extent of motion of the index under given pressures, or in the position of the zero point. The writer has been led to the conclusion that a plain flat steel plate is preferable to any other form in certainty of action and durability; and that the area acted upon by the pressure should be considerable, so as not to require the plate to be excessively thin. The latter object is still further promoted in the present gauge by the adoption of two plates bulging in opposite directions, by means of which the extent of indication on the dial is doubled.

Another important point is that the connection or bearing of the arms upon the plates should be direct and constant, and at the same time without having any actual attachment to the plates, in order that the plates may be plain and undisturbed, without any hole in them or any lump fixed upon them, so as to avoid anything that would interfere with their free elastic action and durability. Also as the extent of motion has to be considerably magnified by means of a lever, it is necessary that the fulcrum on which the lever works should be preserved absolutely immoveable with reference to the plates, as a slight yielding or variation in the fulcrum would cause a serious error in the position of the index and the corresponding indication of pressure. In the present gauge both these points are directly provided for; the two pressure plates have the bearing points of the two arms E and G simply resting upon the centres of the plates, both being kept in steady uniform contact with the plates by the single tail spring I; one of these arms E forms the lever by which the motion is communicated to the index and magnified, and the other arm G forms the sole fulcrum for that lever, quite independently of the frame of the instrument, the two spring

attachments of the arms to the frame having the effect simply of preventing the ends of the curved arms from getting displaced from the centre of the plates.

For communicating rotary motion to the index, the rack and pinion is considered by the writer to be the most eligible plan, on account of the simplicity and directness of its action; and by this means in the present gauge the motion is communicated direct from the lever E, without the intervention of any links or other joints. The only link in the gauge is the small curved radius link or distance piece, which simply keeps the ends of the arms E and G at a constant distance apart, without having to communicate any of the motion to the index.

There are now nearly 400 gauges at work on the above construction, ranging from vacuum gauges to a steam pressure of 10 lbs. to 200 lbs. per square inch; about 50 of them have been in regular use for upwards of twelve months, and they have proved entirely satisfactory. One gauge for hydraulic pressure has also been made on the same plan for pressures up to 400 lbs. per square inch, the plates being about $\frac{1}{8}$ inch thick or No. 9 wire gauge.

Mr. Inshaw exhibited specimens of the gauges, and of the pressure plates and other parts of which they were composed; also of the india rubber ring forming the joint between the plates, and the copper ring or keeper for preserving a definite distance between the plates, which he said he had adopted as the best plan after many trials, and had found to stand satisfactorily under all pressures.

He stated that out of 400 gauges at present made not any perceptible set had been observed in the pressure plates, after subjecting them to three times the pressure they were intended to indicate; and though the trials

were often repeated, no variation took place, the plates appearing to retain their elasticity completely. The large air chamber at the bottom of the gauge prevented any water from remaining between the plates, since if any water entered between them, the air in expanding drove it out again, and there was therefore no water left in the gauge to cause injury in case of frost; up to a pressure of 150 lbs. per square inch however it appeared that no water could enter between the plates.

He showed also a registering pressure gauge, having a second independent index, which was pushed forward by the index of the gauge, and retained in the position to which it was pushed by a slight pressure of its extremity against the glass covering, thus indicating the maximum pressure that had been attained in the boiler during any period, so that any excess of pressure beyond the working limit was at once detected. The friction of the extremity of the registering index against the glass was made use of for setting it back to the zero point by means of turning round the glass in that direction, the friction causing the index to be carried round with the glass, and the glass being then locked by a pin in the new position.

The Chairman asked whether the dials were graduated by trial after the gauges were made.

Mr. Inshaw replied that the dial was made first with a uniform graduation, and the gauge then adjusted to it; the inclined plane bearing surface at the end of the second lever afforded the means of regulating the gauge at the time of construction, so as to agree with the uniform graduation on the dial. The gauges were all tried with a mercury column, and the adjustment was effected by slightly altering the distance of the bearing on the inclined plane from the fulcrum; the inclined plane and hooked end of the first lever were then casehardened, which preserved them from further wear.

Mr. Fernie said he had seen the working of 8 or 10 of these gauges, which had been employed for 6 or 9 months on locomotives upon the Midland Railway; they had been found to work very well and satisfactorily, and had proved equal to any they had tried, and none of them had got out of order yet. He thought the construction of the gauge was a good one, from the simplicity and strength of the parts; it appeared likely to keep in good order for a long time, from the little risk of wear or derangement to which it seemed liable. An easy method of re-adjusting the gauge to the pressure if necessary, without requiring alteration of the dial, was afforded

by the small adjusting screw forming the bearing point of the back centre piece, by which the points of contact of the levers could be always kept close up to the plates.

Mr. Fothergill enquired whether there had been any occasion to apply the adjusting screw in that manner; and whether the gauge had afterwards been tested throughout by a mercury gauge to ascertain if the graduations of the dial all remained correct, as such an adjustment of the zero point might derange the graduation.

Mr. Fernie said he had not had occasion to alter any gauge at present, not having found them get incorrect. They were now making a pump to test all pressure gauges, so that every time an engine came in the pressure gauge should be regularly tested as well as the safety valves.

Mr. Inshaw said that in order to ensure accuracy in originally setting the gauges he employed a testing apparatus with a mercury column going up to 240 lbs. per square inch pressure, by which every gauge was tested and adjusted; this consisted of a glass tube, $\frac{3}{8}$ inch bore and 20 feet long, which was graduated for pressures from 1 to 120 lbs. per inch, the lower end being fixed in a closed mercury box, and the required pressure was produced in it by means of a water tube from a small force pump with an air vessel, upon which the pressure gauge to be tested was screwed. The higher pressures were measured by a similar mercury tube of double length, the lower half of which was made of iron and sunk in a well for convenience of access to the graduated portion.

The Chairman enquired what amount of convexity of the steel plates was produced by the pressures to which they were subjected; unless the deflection were very little he thought it might be affected by the yielding of the attachment of the plates round their edges, that portion of the plates being drawn inwards when they were bulged in the centre.

Mr. Inshaw replied that the total deflection of the two plates was only about $\frac{3}{32}$ inch at most on the diameter of 4 inches under the highest pressure used, the deflection of each plate being only half that amount, so that the stretch or pull upon the circumference must be quite inappreciable. He had first tried several other forms for the pressure plates, such as bell-shaped plates with the convex and with the concave sides outwards; but the surplus steel was then in the way, and the plates did not come back readily enough to their original position when the pressure was removed. After a great number of experiments he came to the conclusion that plain

flat plates were always the most certain and the best suited for the purpose, and they recovered their original position without permanent set. The chief difficulty was to get the plates of exactly the required quality and strength throughout.

The CHAIRMAN observed that the accuracy of the gauge would depend on the plates being uniform in thickness and tempering at all parts.

Mr. INSHAW said the plates were ground down to the exact thickness required for the gauge, to ensure their accuracy and uniformity, and the variation in the deflection was then counteracted by adjusting the inclined plane bearing of the levers.

The CHAIRMAN remarked that the new gauge seemed an accurate and useful instrument, and from its construction well suited to stand the work. He proposed a vote of thanks to Mr. Inshaw for his paper, which was passed.

The following Paper, by Mr. James Clarkson Kay, of Bury, was then read:—

ON AN IMPROVED CONSTRUCTION OF SAFETY VALVES FOR STEAM BOILERS.

The defects experienced in safety valves from their restricted range of action, rendering them insufficient in circumstances of danger from accumulated pressure for the adequate discharge of steam, and uncertain by the defective action of levers, have led to the construction of three varieties of safety valves forming the subject of the present paper.

The object of the first valve is to obtain a discharge of steam equal in amount to the area of the pipe or valve; and to supersede the use of levers, and also to a great extent the use of dead weights.

The object of the second valve is to obtain a discharge of steam equal to the area of the pipe or valve; to supersede the use of levers, and to a great extent the use of dead weights; and, in the event of a vacuum in the boiler, to admit the atmosphere in the same proportion as to area as when the steam is discharged.

The object of the third valve is to obtain a discharge of steam equal to the area of the pipe or valve; to supersede the use of levers for loading, whereby the dead weights may be considerably reduced; and lastly to secure certainty of action in the event of low water, irrespective of the steam pressure in the boiler at the time.

In the first and second valves, the principle of loading by steam is substituted for dead weights or levers. In the third, the principle of dead weights is retained; but, owing to the reduced size of valve necessary by the unrestricted discharge of steam, the dead weights are considerably reduced.

The first form of safety valve is shown in Fig. 1, Plate 135.

A represents a pipe attached to the boiler; this pipe is provided at B with a seat for a valve C, formed upon a tube D, which after passing through a partition E carries a second valve or piston F, the upper side of which is within a chamber G closed by a cover. Between the partition E, which acts as a guide, and the valve C, is an opening H provided for the escape of discharged steam; above the partition E and beneath the piston F is also an opening I, leading to a chamber K, within which is a valve L

held down to its seat by a weight M within the boiler, and exposed on its under side to the pressure of steam by means of the passage N. The valve L is formed with a cylindrical upper portion which projects into a chamber O not quite steam tight, but allowing a little steam to pass into the chamber, which is open to the atmosphere.

The action is as follows:—when the valve is in the position shown in the figure, the steam being supposed to be below the intended limit of pressure, the valve C is maintained on its seat; this is accomplished by steam from the boiler passing through the pipe A and tube D into the chamber G and there exerting its pressure upon the top of the piston F, which being larger in area than the valve C causes the latter to be kept closed: but when an excess of pressure takes place, then the small loaded valve L will be lifted, and allow steam to pass through the passage I into the space above the partition E, whereby the under side of the piston F will be exposed to a pressure equal to that upon its upper surface, and an equilibrium will be established. The valve C will thus no longer be loaded by steam pressure, and will therefore be free to rise and allow a discharge through the passage H. When the pressure of steam is reduced to the intended limit, the loaded valve L will fall into its seat; steam will then no longer pass through the passage I, and that which remains beneath the piston F will gradually escape to the atmosphere through the chamber O. The equilibrium of the piston F will then be destroyed and the valve C restored to the position shown in the figure.

As already stated, the cylindrical part of the valve L is not quite steam tight, but nearly so, thereby allowing steam to pass into the chamber O, which is open to the atmosphere: the object of this is to prevent the steam which passes into the passage I from pressing upon the top of the valve L; for if such were the case the valve would be acted upon on the upper as well as the under surface by the same pressure, and would therefore be forced to its seat and become inoperative; on the other hand, if the valve were exposed direct to the atmosphere, the steam would blow off without passing beneath the piston F. It is not however necessary that the cylindrical part of the valve L should be otherwise than perfectly free in the chamber O; for if the surfaces be sufficiently close to each other to prevent such an amount of steam blowing off as would reduce the pressure of that which acts beneath the piston F, they will be fitted accurately enough for the purpose.

The second form of safety valve is shown in Fig. 2, Plate 135.

A is a pipe to be attached to the boiler, and upon it is formed a chamber B, within which projects a pipe C open at one end to the atmosphere. The pipe C is provided with a seating, upon which is placed a spherical valve D extending upwards into a cylindrical closed casing E. To the pipe A is connected a passage F, within which there is a spindle G carrying a weight H suspended within the boiler. The spindle G is furnished with a disc I working within a short cylinder K, and of such diameter as to allow a small quantity of steam to pass; above this disc is a valve L fitted on a seating in communication with the chamber M above the spherical valve D.

The action is as follows:—when the valve is in the position shown, steam from the boiler passes through the pipe A to the chamber B, and there exerts its pressure against the lower part of the ball D, tending to raise it; this however is prevented by the pressure upon its upper surface exerted by steam which has passed between the disc I and cylinder K into the chamber M, and this steam will also be supplied through a space left between the spherical valve D and the cylinder E within which it is placed, for those parts are not so fitted as to be steam tight. The apparatus will thus remain until an excess of pressure in the boiler takes place, when the valve L will be raised; and as the area thereby opened will be greater than that between the disc I and its cylinder, the steam in the chamber M will be at liberty to escape, and thus the pressure will be removed from the upper part of the ball D, allowing it to be raised so that a discharge may take place from the chamber B into the pipe C. When the pressure decreases, the valve L will be carried by the weight H to its seat, and steam will again pass on to the upper surface of the ball and effect the loading.

The valve is equally effective in the case of a vacuum occurring in the boiler; for then the loading of the valve is of necessity removed, and the atmospheric pressure lifts the ball and admits air.

The third form of safety valve, shown in Fig. 4, Plate 136, is used either simply as a safety valve for steam, or in conjunction may be fitted up for the purpose of acting in case of low water in the boiler, and will do so irrespective of the pressure of steam in the boiler and whatever may be the size of the valve.

A is a pipe fixed to the boiler, upon which the valve case B is placed. In the valve case B is the valve seating C constructed in the form of a cup, at the bottom of which the valve D is seated; the seating portion of the valve is of a spherical form, and above the valve and forming part of it is placed a disc E, of larger diameter than the valve, as shown enlarged in Fig. 5. The valve is placed on a spindle F, to which is suspended the weight G which loads the valve. The weight G may be made in any form convenient when acting simply for a steam pressure safety valve; but in this case, when the valve is intended to act also as a low water safety valve, the weight is made in the form of a lever, at the end of which is placed a stone float H, the combined weight of the lever, float, rods, &c., less by the weight of water displaced, being the load of the valve.

When the steam pressure in the boiler acting on the underside of the valve D exceeds the load, the valve is raised; and the steam then acting on the enlarged area of the disc E and being partially confined by the cup C, the valve continues to rise until a discharge of steam takes place through the pipe I equal to the area of the pipe or valve seating.

In the case of low water in the boiler, the float sinks as the water lowers; and the increased weight at the end of the lever G brings the brass centre pin L to rest on the fulcrum or stirrup M, and raising the pin N in the loop of the valve rod unloads the valve, leaving it free to the action of the steam; the discharge of steam then takes place irrespective of the pressure of steam at the time or the size of the valve.

Each of these valves is in operation and generally giving satisfaction; but the third form, shown in Fig. 4, on account of its greater simplicity, smaller cost, and combining the advantages of the former valves as to the quantity of steam discharged with the very important addition of certainty of action in case of low water, is most preferred and most extensively in use, and the writer fully believes that it is now found unexceptionable. About one hundred of the valves are now at work.

The small key or auxiliary valve, used in connection with the first and second forms of safety valve, has also an important application and use beyond the purpose to which it is there applied. It may be used as a safety or relief valve for locomotive or any other boilers, where the object is to use the waste or surplus steam by introducing it into other boilers of lower pressure, locomotive tanks or other closed vessels for heating

water, &c. Fig. 3, Plate 135, shows the valve as arranged for this purpose. A is the steam pipe leading from the boiler; B the valve loaded to its seat. This valve is formed with a cylindrical upper part C, which projects into a chamber D not quite steam tight but allowing a little steam to pass into the chamber, which is open to the atmosphere by means of slots E; when the pressure rises above the intended limit the valve will be lifted, and steam will be allowed to pass along the passage F to the boiler tank or other closed vessel. The cylinder C prevents the back pressure of the steam from loading the valve so that its proper action would be obstructed.

Mr. Kay showed models of the second and third forms of safety valve described in the paper, and explained that in the latter, though the valve were loaded to 100 lbs. per square inch pressure, it would act in case of low water if there were only 1 lb. pressure in the boiler, and would continue open until the water level was restored. The supplementary lever on the top of the valve gave the means of reducing the load on the valve below the amount to which it was originally adjusted, so as to make it blow off at a lower pressure; the limit of pressure could thus never be increased beyond the amount first determined upon, but could be diminished at pleasure, and the lever served also for trying whether the valve was free in its action.

Mr. McConnell thought the safety valve last described appeared an ingenious contrivance for relieving the valve of its load when the water got low in the boiler. He enquired whether it had been long in use, and whether any derangement in its action had been experienced; he thought that with bad water a deposit of lime might take place on the centres of the lever and cause it to stick.

Mr. KAY replied that some of the valves had been in constant work for 8 or 9 months, and no failure had occurred in any of them, except that the few first made were too sensitive, the float being too heavy, so that it was too easily moved by a slight fluctuation of the water. There was no fear of any deposit in the boiler interfering with the action of the valve, as $\frac{1}{4}$ inch clearance or more was allowed in the stirrup all round the centre pin, and the whole was situated in the steam space, where the deposit could be but small. Moreover any accumulation of deposit on the centre of the lever or in the stirrup would not impede the action of the valve, but would merely cause it to blow off sooner than intended, by diminishing the range of the float, and would thus call attention to the defect.

The CHAIRMAN enquired how many of the valves were now at work, and what was their cost, and whether any of them had been put up in that neighbourhood.

Mr. KAY replied that about 100 of the valves were now at work, about 80 of them being low water valves, the cost of which was about ten guineas; they were at present in use only in the neighbourhood of Manchester. A few of the first and second forms of valve had been in use about 2 years, and answered their purpose efficiently, giving a large opening for discharge of steam, while the pressure to be overcome in opening the valve was only that upon the small auxiliary valve. He had however found some risk in employing that form of valve on his own boiler, as the boiler after a month's work with bad water was subject to prime from the accumulation of dirt, and the tendency to prime was increased by the sudden opening of the large area of the discharge valve; on one occasion the valve discharged so much water as nearly to cause mischief by the extensive lowering of the water level in the boiler. In the low water valve the action was very easy and gradual; the valve was opened gradually by the pressure of the escaping steam upon the enlarged disc or flange on the top of the valve.

Mr. MCCONNELL observed that it was essential that all safety apparatus for boilers should be as simple as possible, and not liable to be injured by deposit from the water. All self-acting apparatus that was not self-acting always was particularly to be avoided; and it would therefore be desirable to try the valve under as severe a test as possible, with very dirty water and in the most disadvantageous circumstances. The valve described was certainly an ingenious and beautiful arrangement, and

appeared likely to ensure safety both against excess of pressure and against low water.

Mr. Inshaw had recently seen a safety valve tried in that neighbourhood, constructed on a similar principle to the one first described, having a large escape valve kept down by the pressure of the steam upon a piston above the valve; the steam was admitted above the piston by a small side valve, and whenever the pressure in the boiler got too high, the steam was shut off by the small valve closing, and the large escape valve was instantly forced open by the unbalanced pressure on the underside, allowing the steam to escape through its whole area. He had observed an objection however to its action, that the steam did not escape in a continuous stream, but with a sudden rush at the moment of the large valve opening; and the valve then shut again violently, the pressure being suddenly lowered by the escape of the excess of steam, causing a succession of severe blows, which he thought would be injurious to the apparatus in regular work.

Mr. Kay said that no objection of that kind had been experienced with the valve described in the paper, which opened and shut gradually; but in the first and second forms of valve there was sometimes a tendency to discharge water through the valve, owing to the sudden rush of steam through so large an opening; and he had been led decidedly to prefer the last form of valve described, which was free from that objection.

Mr. Fothergill observed that the action of the last mentioned form of valve appeared to depend upon the enlarged disc or flange on the top of the valve, which was said to be of considerable advantage by giving an increased area so as to increase the opening of the valve; he wished to know whether the ratio at which the opening of the valve increased compared with an increase in the area of the disc had been ascertained, as it would evidently not increase so fast as the area of the disc, on account of the diminished pressure that would be exerted by the expanding steam upon the overhanging flange above the valve.

Mr. Kay replied that the increase of area of the valve afforded by the disc was found sufficient to open the valve wide; but the size of the disc had been only approximately determined from the results of trials in the several cases, and varied with the pressure of steam, a smaller area of disc being required with high pressure than with low pressure steam. The form of the cup also affected the valve, by directing the current of steam more or less upon the disc. In constructing the valve it was loaded to the

limit of pressure intended in the boiler, and the size of the disc was then adjusted so that the valve should be fully opened by the escaping steam, without requiring the pressure in the boiler to fall so much as 1 lb. per square inch below the limit before the valve shut again.

The CHAIRMAN thought the valve appeared a simple and effective apparatus, and worthy of consideration, as it answered the double purpose of a safety valve and a low water valve. He proposed a vote of thanks to Mr. Kay, which was passed.

The following Paper, by Mr. John Wilson, of Westbromwich, was then read :—

DESCRIPTION OF A NEW CONVEX-PLATE LAMINATED SPRING.

Laminated steel springs are of comparatively recent date, their introduction having taken place within a century from the present time. Before that time, lance-wood, whalebone, oblique leather braces, and other similar contrivances were adopted to give a slight amount of ease to the motion of the slow going vehicles used in those days, an example of which still exists in Her Majesty's state carriage, constructed a century ago, which is without springs, being merely suspended by oblique leather braces from four curved standards. The laminated steel springs have since become universally used in common road vehicles; and the same plan was adopted generally on railways, the form and proportion of the springs being modified to suit the altered circumstances. Many and various have been the contrivances introduced with a view to supersede the laminated spring, more especially for railway vehicles, but the laminated spring is still generally adhered to; indeed it is so simple in construction, and so easy in action, when properly made and proportioned, and at the same time so cheap, that it appears likely to be a long time before anything is introduced that will effectually supersede it. The only important objection which in the writer's opinion attaches to the laminated spring is its weight; and accordingly in the new form of laminated spring described in the present paper he has endeavoured to remove or materially diminish this objection, and at the same time to introduce an improved and simpler mode of construction.

Having been long engaged in the manufacture of springs for common road carriages as well as for railways, the writer has frequently had the subject of the weight of the ordinary springs pressed upon his attention, especially in reference to the bearing springs for common road vehicles in hilly districts, where reduction of weight becomes a particular object, and the springs form a considerable item in the total weight, in some instances amounting to a fifth of the whole weight of the vehicle. The idea occurred to him about a year ago that grooved or trough plates would have a much greater stiffness than the ordinary flat plates, as in the case of corrugated compared with plain plates; and if it were practicable to use them in springs, a great reduction in weight of steel might be effected with the same deflection and length of spring. A considerable doubt was felt at first

about the practicability of employing plates of such a form for the purpose, from their being too rigid to stand satisfactorily the continued and violent bending to which a spring is subjected; but on making a number of experiments with steel of various widths and thicknesses and different extents of convexity, it was found that with a moderate convexity, not exceeding in extent the thickness of the plate, the strength was so much increased that a thinner steel could be used, and the action was thoroughly satisfactory, the convex plates standing the work fully as well as the ordinary flat plates. A pair of springs was then made for a two-wheeled dog-cart, which has now been in constant work for seven months on rough roads in Scotland, and the springs have proved entirely successful. They have stood the severe test to which they have been subjected without any sign of failure, their action has been highly approved for ease of motion, and they have effected a saving of one third the weight of the springs ordinarily used for the same purpose. A specimen of a nearly similar spring is exhibited to the meeting.

The construction of the new spring is shown in Figs. 1 to 7, Plate 137, which represent its application to the several kinds of railway bearing springs.

Fig. 1 is a side elevation of a wagon bearing spring with rolled eyes for shackles. Fig. 2 is a side elevation of a wagon bearing spring with thickened ends. Fig. 3 is a transverse section of the spring, showing the series of plates of steel with their convex form; and Fig. 4 is a corresponding plan. Fig. 5 is a longitudinal section of a wagon bearing spring, showing the adaptation of the convex plates for springs with the plates separated in the middle. Fig. 6 is a side elevation of a carriage bearing tension spring. Specimens are also shown on the table of a carriage buffer spring, and of a grasshopper spring and an elliptical spring for common road carriages.

In the manufacture of these springs, the steel is rolled with the required amount of convexity, and the plates are then cut to the proper length and made up in the usual manner. In consequence of the convexity of the plates, the necessity of studs and slots at their extremities is obviated, and the plates are effectually prevented from working askew by the convex top of each plate sliding in the groove formed by the concave underside of the plate above; the steel is thus preserved uninjured in strength, and the

labour and expense of forming the studs and slots is saved. The only fastening required is to prevent the plates shifting endways over one another during working; and for this purpose, instead of the ordinary fixing rivet or bolt passing through the centre of the plates and clip, a small fixing pin is driven down at one side of the spring, as shown in Figs. 3 and 4, a little more than half its thickness being in a groove in the side of the clip, and the remainder fitting into a notch in the edge of each plate; these notches however do not extend into the plates beyond merely the rounding of the edges of the steel, and the strength of the plates is thus preserved entire, instead of being diminished to the extent of about 7 to 14 per cent. as is the case with the ordinary holes cut through the centre of the plates. In the new springs the centre clip is also made shorter than in ordinary springs, whereby a freedom of action is allowed to the plates almost to the very centre, and the weight of clip is also reduced.

The principle on which the convex plates act is the same as that of an inverted trough girder or beam, having one horizontal flange and two vertical side ribs; if such a beam were supported at the centre and weights hung at the extremities, it is evident that, if made of steel, it would be strongest when placed with the horizontal flange upmost, in the form of an inverted trough; the horizontal flange would then be subjected to tension, and the side ribs to compression. In accordance with this principle, the convex plates in the new springs are placed with the convexity upwards, so that the edges of the plates are under compression and the centre portion in tension. On this account the small notches in the plates for the fixing pin do not diminish the strength of the spring, that part of the plates being in compression. If the position of the plates were reversed, so as to have the convexity downwards, the edges of the plates would be in tension and the centre part in compression, and the strength would be much reduced; and accordingly it was found in trying a plate, 14 inches length of bearing and 3 inches broad, placed with the convexity downwards, that under a load of $1\frac{1}{2}$ tons it broke with a fracture commencing at the edge and proceeding diagonally inwards in the manner of a tear. This plate is exhibited on the table. On the other hand, when placed with the convexity upwards, the fracture would have to commence at the centre and proceed in both directions at once to the two sides; but the experiments for the purpose of breaking a plate in this manner have failed of producing a fracture, except in one instance

where the plate was left purposely too hard and snapped right across; in all the other instances the plates were merely flattened and spread crosswise, and bent in the manner of the specimen exhibited, with a load of 1½ tons.

The results of trials made with the different kinds of springs shown in the drawings are given in the Table appended; and the springs tried are before the meeting. The new springs tested were all made with $\frac{5}{16}$ inch steel, and in order to afford a correct comparison with the ordinary springs, a spring of each description was taken of $\frac{3}{8}$ inch flat plates made to the ordinary patterns, of such dimensions as to have the same deflection per ton as the new springs. It then appears from the experiments that, for the same deflection per ton, the new springs made of $\frac{5}{16}$ inch convex plates saved 25 per cent. or one quarter of the weight of the ordinary springs made of $\frac{3}{8}$ inch flat plates. From a similar comparison of the new springs with ordinary springs made of $\frac{5}{16}$ inch flat plates, it appears that the new springs in this case save 33 per cent. or one third of the weight, for the same deflection per ton.

In the spring shown in Fig. 7, the ends of the plates are separated for the purpose of diminishing the upward rebound or play of the spring. The method usually adopted to effect this object is to employ a straight tension bar, strained tight along the top of the spring, connected with the scroll irons by suspending links, and bolted down to the spring in the centre, so that the action of the spring is confined within narrow limits, avoiding undue disturbance of the level of the buffers of the carriage; this plan however has the disadvantage of throwing a very great strain on the sole bars, which have to be strongly trussed in order to prevent "hogging." The proposed plan, shown in Fig. 7, is intended to obviate these objections, and to relieve the sole bars of a part of the strain thrown upon them. In the ordinary springs, the greatest strain is thrown upon the shortest plates, by what is technically called the spring of the plates; that is, each succeeding plate from the longest has more curvature than the preceding one, and the shortest plate most of all. However correct this plan may be for common road carriages, the writer is of opinion that for railway carriages moving at such high velocities, on an almost level road, and meeting with but few obstructions, it is not applicable; and this opinion is borne out by the almost universal adoption of the tension bar on the top of the springs of four-wheeled railway carriages. A railway bearing spring is required to

Experiments with New Convex-Plate Springs.

Description of Spring.	Length of Bearing. Straight.	Weight of Steel.	Number of Plates.	Thickness of Plates.	Load.	Camber.		Deflection.		Permanent Set.
						Before.	After.	Total.	Per Ton.	
WAGON BEARING SPRING.	Ft. Ins.	Lbs.	No.	Inch.	Tons.	Ins.	Ins.	Ins.	Ins.	Inch.
Sliding End — New — Open ...	2 10	37	6	$\frac{5}{16}$	$2\frac{1}{2}$	4·35	1·50	2·85	1·14	0·05
Sliding End — New — Close ...	2 10	42	8	$\frac{5}{16}$	3	3·86	1·34	2·52	0·84	0·06
Sliding End — Old	2 10	58	9	$\frac{3}{8}$	3	4·20	1·65	2·55	0·85	0·07
Shackle End — New — In Tension	3 6	66	9	$\frac{5}{16}$ *	3	4·43	0·67	3·76	1·25	0·00
Shackle End — New — Loose ...	3 6	66	9	$\frac{5}{16}$ *	3	5·90	2·45	3·45	1·15	0·00
Shackle End — Old	3 6	82	10	$\frac{3}{8}$	3	6·10	1·95	4·15	1·38	0·05
CARRIAGE BEARING SPRING.										
New — Open ...	5 2	64	7	$\frac{5}{16}$	1	5·73	0·62	5·11	5·11	00
New — Close ...	5 2	63	7	$\frac{5}{16}$	$1\frac{1}{2}$	6·60	0·18	6·42	4·28	0·00
Old	5 2	92	8	$\frac{3}{8}$	$1\frac{1}{2}$	6·29	−0·30	6·59	4·39	0·00
CARRIAGE BUFFER SPRING.										
New	6 0	121	12	$\frac{5}{16}$	2	12·20	2·75	9·45	4·72	0·00
Old	6 0	168	14	$\frac{3}{8}$	2	11·65	2·24	9·41	4·70	0·00

In all the springs, of both new and old patterns, the width of the plates is 3 inches.

* One plate $\frac{3}{8}$ inch thick, the rest $\frac{5}{16}$ inch.

possess steadiness, so as to hold the axlebox steady independently of the axle guard, with just sufficient elasticity to yield a little to the inequalities of the road and to diminish the vibration caused by the great velocity at which the wheels run upon the rails.

The new springs are from 25 to 30 per cent. lighter than the ordinary springs for the same strength, and are consequently also cheaper. The convex form of the plates renders them less liable to rust, as water and dirt cannot so readily lodge between them. The absence of studs and slots and of holes for the centre pin prevents loss of strength and injury of the plates, rendering them less liable to breakage. The plates can also be made of thinner steel, in consequence of the strength given by the convex form; and in the springs exhibited the plates are all only $\frac{5}{16}$ or ·31 inch thick. The new springs also do not deflect so much under a given load, when made of the same dimensions as the ordinary springs, and therefore require less camber, an advantage which renders them peculiarly adapted to railway carriages.

Mr. Wilson exhibited a specimen of one of the new double elliptical springs in action by means of a lever fixed in a frame, showing the ease and freedom of motion of the spring. Also a number of specimens of different forms of the new spring, and detached plates that had been experimented upon to ascertain the mode of fracture.

The Chairman observed that the convex form of the plates certainly rendered them more rigid; and he enquired whether fully the same elasticity could be obtained as with the ordinary flat plates.

Mr. Wilson said the plates were made considerably more rigid than flat plates of the same thickness, but the same elasticity was obtained by using thinner steel. The reduction in weight of the springs was made both in thickness and number of plates; the new 3 feet wagon bearing spring had only 8 plates weighing 42 lbs. of steel, instead of 9 plates weighing

58 lbs. as in the ordinary spring, both having the same total strength and elasticity, carrying 3 tons load with a deflection of 0·85 inch per ton; the new spring thus saved 27 per cent. of the weight.

The Chairman asked whether the convexity was varied with the width of the plates, and in what ratio.

Mr. Wilson replied that the convexity was varied according to the width and thickness of the plates, and the purpose for which the spring was intended; but as a general rule the plates were curved to a radius equal to their own breadth, 1½ inch steel being curved to a radius of 1½ inch, and 3 inch steel to a radius of 3 inches.

Mr. McConnell enquired what strain the new springs had been subjected to in testing, and whether their permanent set was found to be more than that of common springs.

Mr. Wilson replied that the 3 feet and 3½ feet wagon bearing springs had been tested up to 3 tons each, without showing any permanent set after having been once subjected to the full load to bring the plates to their fair bearing. If strained beyond the load they were calculated to bear, they would be somewhat more liable to permanent set than old flat plate springs, on account of the greater rigidity of the steel; but they were less liable to break, because under severe strain the convex plates had the power of yielding by spreading laterally or flattening, as shown by the specimens exhibited, instead of breaking across as the thicker flat plates did.

Mr. Fernie enquired what was the expense of fitting the plates in making the new springs; he supposed it would be rather more than in flat plate springs.

Mr. Wilson said the fitting was a little more expensive, but the difference was inconsiderable, and there had not been any practical difficulty experienced in it; the expense of the slots and nibs required in the ordinary flat plate springs was also entirely saved.

Mr. McConnell asked whether there was found to be any difficulty in tempering the convex plates, from their twisting and cracking in the process, or changing their convexity.

Mr. Wilson said there was not found to be any difficulty in tempering the convex plates, and no material difference in that respect from the ordinary flat springs, and the plates were worked in the same way; they were rather more liable to twist, but were readily set straight in the ordinary fitting.

The CHAIRMAN thought the new spring was an ingenious mode of diminishing the weight of steel, whilst retaining the strength and elasticity; he suggested trying an experiment with a bar rolled in the form of a rectangular trough, as referred to in the paper, to ascertain the relative strength and elasticity.

Mr. ROSS said he had made a trial of the new springs as bearing springs for railway wagons, and had had one set working under a coal wagon for 3 months; he had not yet obtained the particulars of their working, as they were on a distant line, but he had not had any complaint respecting them. He had tried them previously in a testing machine, and was surprised at their elasticity and freedom of action; the springs were also remarkably light, weighing only 56 lbs. each, instead of 76 lbs. the weight of the corresponding ordinary springs, making a saving of 25 per cent. of the weight; and a reduction of 80 lbs. of steel in each wagon caused a considerable saving in cost. From the greater stiffness of the plates he thought it might be found advisable to make the new springs longer than ordinary springs, to obtain the same amount of elasticity; this construction appeared well suited for heavy railway springs, but more trial was required to decide whether it would answer well for lighter springs.

Mr. MCCONNELL remarked that the permanent saving in dead weight effected by the new springs was even more important than the original saving in first cost. The weight of the present railway springs was undoubtedly a serious objection, particularly in the case of the laminated buffer springs, in place of which india rubber springs and various kinds of spiral springs had been introduced, on account of their saving in weight. There could be no doubt that the laminated springs were by far the best for buffers, being more easy in their action and more to be depended upon; and therefore a saving of 25 per cent. of their weight would be very valuable. In bearing springs the convex plates from their greater stiffness would allow of longer and easier springs being used, which would be a great advantage in railway carriages.

He proposed a vote of thanks to Mr. Wilson, which was passed.

An abstract was then read of the Paper that had been read at the previous meeting at Manchester, "On a Standard Decimal Measure of Length for Mechanical Engineering Work, &c.," by the President, (Proceedings, June, 1857), the discussion of which was then continued.

The CHAIRMAN regretted that the President was unavoidably prevented from being present as he had expected to be; he felt a great interest in the question of decimal measures, and was very desirous to have it practically carried out. It seemed to be agreed that the change was highly desirable, and the members had resolved at the Manchester meeting to adopt the system as far as might be practicable and useful. The subject was one requiring careful consideration, as to the best way of effecting the proposed alteration.

The necessity for more minute and accurate means of expressing dimensions had arisen from the great improvements effected in workmanship, greater accuracy of work being now obtained than could be practically expressed by the old fractional system. The President had succeeded in measuring minute distances by touch much more finely than was even practicable by the microscope, and had shown that much smaller quantities than were ordinarily thought of were readily appreciated by the sense of touch.

In the scale of standards of size for mechanical engineering work, it was proposed to express all the sizes in thousandths of an inch, so as to include all the present eighths of an inch, in order to avoid the inconvenience and loss that would be caused by abandoning them, at the same time interposing smaller intervals of ·050 or ·025 inch in order to carry the subdivision to any extent that might be required in work.

The proposed wire gauge scale he thought was a very good one and appeared quite complete, taking in all the sizes at present in use; it would tend greatly to increased accuracy of workmanship, and would prevent the present uncertainty and differences, which occasioned serious difficulties in metal manufactures. It would be a general convenience to adopt one

uniform scale, in place of the several scales now in use, which both differed in the names for the same size and progressed in opposite directions; in their place the proposed scale would simply substitute the actual values in thousandths of an inch, thus making the wire gauge scale identical with the scale of standards of size for taps and dies.

Mr. McConnell said he had cordially supported the President's proposal in the discussion of the question at the Manchester meeting, having felt that the general adoption of the decimal system of measure would prove a great advantage in all mechanical work, by increasing the accuracy of workmanship and removing the complication arising from the present imperfect mode of fractional expression. He had since had opportunities of discussing the matter with several heads of large establishments, who agreed fully in the proposal and thought it highly desirable to start at once. One only of those he had spoken to about it thought that another unit preferable to the inch might possibly be found, but was not prepared with a better one to propose. He thought the inch was the only practicable unit to be adopted for the present purpose, as it was so intimately involved in the dimensions, calculations, and manufacture of mechanical work of all descriptions.

As a next step towards carrying out the object, he proposed "That the President and Council of the Institution be requested to act as a Committee, with power to add to their number, for the purpose of getting the proposed decimal system of measure carried into effect." The committee would of course consult the best authorities, and any scientific gentlemen who could aid in carrying out the object.

Mr. Fenton seconded the resolution, and observed that the committee would of course be glad to receive suggestions from any of the members in furtherance of the object.

The Chairman observed that the question of decimal measures had often been discussed, and had attracted the attention of the legislature as well as of the public; but the difficulties of dealing with it as a whole were such that there appeared little chance of anything being accomplished, unless those who were practically affected by it took it up. Before the next meeting he hoped the committee would be able to collect such information and give the subject such consideration as would enable them to mature some plan to be submitted to the meeting.

The resolution was then put and carried unanimously.

Mr. Inshaw considered there was no doubt the proposed wire gauge scale would be found a great advantage, especially in that district; it was much wanted, in consequence of the unsatisfactory and complicated state of the present gauges used in metal manufactures, which sometimes occasioned disputes about size that could not be properly decided, owing to the want of an exact standard of measure. He had experienced this objection in the difficulty of obtaining plates of the exact thickness required for his pressure gauges.

Mr. McConnell observed that the general employment of decimal dimensions in drawings and specifications was desirable as a first step, that the work might be already started on the decimal system before being put into the workman's hands. If the workmen saw drawings figured in decimals, as for example 1·75 inch instead of $1\frac{3}{4}$ inch, it would lead them gradually to abandon the present fractional divisions of the inch. It might perhaps be best at first not to attempt any other change in the ordinary two-foot rule than dividing the inches into tenths instead of eighths or twelfths, in order to familiarize the workmen with the decimal subdivision of the inch, as a first step towards carrying out the system more completely.

Mr. Ross said he had been much struck at the Manchester meeting with the importance of the President's proposal, and felt satisfied of its advantage and practicability. He had been considering since that meeting about the mode of carrying it into practice, and what instruction the workmen would require to prepare them for the change; and had come to the conclusion that only inches should be talked of, instead of expressing the dimensions in feet and inches, thus dropping the foot altogether for the purpose, and having all drawings and dimensions marked in inches throughout. He considered this plan would prove simpler and more convenient in his own work of railway carriage and wagon building, without involving any real objection; and for this purpose he had got a 50 and a 100 inch rod made with all the inches divided into tenths for the use of the foremen; and also a 20 inch carpenter's rule divided into tenths for the workmen. He thought the difficulty of effecting the change would be much less than might be expected at first, and did not anticipate any difficulty with regard to the workmen, as ordinary workmen would readily fall into the way of using tenths instead of eighths of an inch. The facility with which a new measure could be introduced was shown by a case that had occurred recently at their works at Birmingham, where one set of

men were put on to a lot of carriage stock for a French railway which had to be constructed from French drawings, and the dimensions were all first translated from the metres with considerable trouble, and marked in English feet and inches upon the drawings; but the men had themselves appealed for French metre rules, to work direct from the original dimensions on the drawings, and had carried out the whole work in that way without any difficulty, returning afterwards to their ordinary rules. He felt no doubt that they would also readily get into the way of using inch rules decimally divided, in place of their present rules with feet, inches, and eighths; and with a higher class of workmen, as in engineering shops, there would of course be still less difficulty in getting them to understand the new system.

The CHAIRMAN was glad to hear of the start made in the employment of the decimal system, and was confident that it required only a persevering trial by those practically concerned, to ensure its being successfully carried out. With regard to the foot, it would certainly make the system more complete if the foot could be shortened to 10 inches instead of 12 inches; but such a change was impracticable at present, and the desired object was in effect accomplished by keeping the dimensions entirely in inches, instead of feet and inches; using only inches and decimals, as in the French system only metres and decimals were used.

The Meeting then terminated.

PROCEEDINGS.

October 28, 1857.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 28th October, 1857; Sampson Lloyd, Esq., in the Chair.

The Minutes of the last General Meeting were read by the Secretary and confirmed.

The Chairman announced that according to the rules of the Institution, the President, Vice-Presidents, and five of the Council in rotation would go out of office in the ensuing year; and that at the present Meeting the Council and Officers were to be nominated for the election at the next Annual Meeting.

The following nomination list was adopted by the Meeting for the election at the Annual Meeting:—

PRESIDENT.

John Penn, ...	London.

VICE-PRESIDENTS.

(Six of the number to be elected.)

Alexander B. Cochrane, . .	Dudley.
William Fairbairn, . .	Manchester.
James Fenton, ...	Bradford.
Benjamin Fothergill, . .	Manchester.
Sampson Lloyd, ...	Wednesbury.
Henry Maudslay, . . .	London.
James E. McConnell, . . .	Wolverton.
John Ramsbottom, . . .	Crewe.
Joseph Whitworth, . . .	Manchester.

COUNCIL.

(Five of the number to be elected.)

Charles Beyer,	Manchester.
Samuel H. Blackwell,	Dudley.
Edward Fletcher,	Gateshead.
Sir Charles Fox,	London.
Robert Hawthorn,	Newcastle-on-Tyne.
James Kitson,	Leeds.
J. Scott Russell,	London.
Michael Scott,	Blyth.
William Weallens,	Newcastle-on-Tyne.
Henry Wright,	Birmingham.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for that purpose, and the following New Members were duly elected:—

MEMBERS.

John Macmillan Dunlop,	Manchester.
John Gregory,	Lisbon.
John Pitt Kennedy, Lt.-Col. R.E.,	London.
John Laybourn,	Newport.
George Frederick Muntz,	Birmingham.
John Taylor Thompson,	Newcastle-on-Tyne.

The following Paper, by Mr. Charles Markham, of Derby, was then read:—

DESCRIPTION OF NAYLOR'S DOUBLE-ACTING STEAM HAMMER.

The extraordinary development and improvements that have taken place within the last ten years in the manufacture of large masses of wrought iron may be attributed in a great measure to the application of the Steam Hammer, the original invention of Mr. Nasmyth and subsequently modified by Condie and Morrison. Steam hammers that have hitherto been constructed involve the same general principle of being lifted by steam and falling by gravity, the effect of the blow being dependent on the weight of the hammer, multiplied by the height of its fall. The greater the distance it falls and consequently the greater the force of the blow, the slower is the speed of working. The great practical drawback to the more extended application of steam hammers has been the impossibility of obtaining sufficient speed or quickness of stroke, as an ordinary 25 cwt. hammer is not capable of being worked at a greater speed than 60 strokes per minute with the self-acting gearing.

This serious difficulty has been overcome in the 25 cwt. double-acting steam hammer invented by Mr. William Naylor of Norwich, forming the subject of the present paper. It is the largest hitherto made on this principle, and has been constructed by Mr. Eastwood of Derby.

One great advantage that is derived from the application of this hammer consists in its being capable of working up to 200 strokes per minute, which is from 3 to 4 times faster than any steam hammer that has hitherto been constructed. The velocity that has been obtained from the new 25 cwt. hammer is considerably greater than is required in practice, for experience has proved that a speed of 120 strokes per minute is as great as can be applied to enable the forgeman to preserve the form of bar that is being drawn under the hammer; but this velocity is necessary in the ordinary manufacture of iron, and a higher speed may be applied with still greater advantage to lighter hammers of 8 or 10 cwt. The new hammer does not depend only upon the distance it falls for the effect of the blow, being either single or double-acting: that is, single-acting by being merely lifted by steam and falling by its own gravity; or double-acting by being capable of having any amount of steam admitted upon the upper

side of the piston, at a pressure varying from that of the atmosphere to the full pressure of steam in the boiler. It can also be made to work horizontally with great rapidity, when gravity gives no aid, and be used in that manner as a rivetting machine; or it can be used in direct opposition to gravity, as in rivetting upwards. The momentum of the hammer gives the effect of the blow, and it matters but little in what direction the hammer is moving, so that it moves fast enough.

If a steam hammer were constructed with a stroke of 16 feet and made to fall freely through that space, it would take one second of time in falling, and the hammer would have acquired a velocity of 32 feet per second when it came in contact with the anvil. Now if this hammer were projected upwards with a velocity of 32 feet per second, it would take one second in being lifted 16 feet, and only 30 blows per minute could be obtained. Similarly, there would be 120 blows per minute if the distance of fall were but 1 foot; but then the final velocity of the hammer would be only 8 feet per second at the end of its fall or when the blow was given. Now if the hammer were projected upwards with a force sufficient to carry it 16 feet, but when it had gone 1 foot it were met by an elastic force powerful enough to stop it and drive it back again, it would return with a velocity equal to what it would have acquired in a fall of 16 feet. Then taking the difference in time between a fall of 15 feet and a fall of 16 feet as the actual time of the fall of the hammer, there would be obtained 937 blows per minute of the same force as would have been given by a fall of 16 feet, instead of the 30 blows per minute obtained by the action of gravity alone with that fall. Now since the double-acting steam hammer does not depend entirely upon the distance it has fallen for its effect of blow, nor upon its rise being counteracted by gravity to cause it to return, as it is met by the steam above the piston, the velocity of its working becomes a mere question of relative force and weight for whatever speed and effect of blow may be required. The above comparison shows that when the hammer is raised 1 foot with a velocity sufficient to raise it 16 feet, but is forced back after it has risen 1 foot, the effect of the blow is just the same as if it had risen 16 feet and fallen without any other power than gravity; but in point of number of blows in a given time the short range shows an advantage of 31 to 1. As the actual case of a steam hammer differs from the supposed case, in the moving force being continuous in raising the hammer instead of merely a single impulse at the commencement

of the stroke, though there will not be so much gain in number of strokes, the advantage is still very important. If there were two similar hammers employed on the same work, one double-acting and the other single-acting, the former would be capable of striking so many more blows on the iron while it is hot as perhaps to finish the work at one heat, while the latter from its slow motion suffers the iron to cool before it does much execution upon it, and consequently not only is there a waste of fuel and great loss of time by the repeated heating of the iron, but the material also suffers by deterioration.

The construction of the improved 25 cwt. steam hammer is shown in Figs. 1, 2, and 3, Plates 138 and 139. Fig. 1 is a front elevation of the hammer with the steam cylinder in section; Fig. 2 is an enlarged vertical section of the steam cylinder and valve chest; and Fig. 3 is a sectional plan. Figs. 1 and 2 show the steam cylinder A with the piston B. On the top of the cylinder is an inverted valve C, held up to its face by a slight spiral spring; the object of this valve is to prevent a vacuum being formed in the upper end of the cylinder while the hammer is working single-acting or without steam above the piston. The piston B is made solid with the piston rod, which is of large size, being 7 inches diameter, and forms part of the weight of the hammer; the piston rod descends through the stuffing box in the bottom cylinder cover into the hammer block D.

The valve chest or chamber E, Figs. 2 and 3, is cast with the cylinder, and is of itself cylindrical, with passages or ports communicating with the cylinder near the top and bottom ends: opposite to the port at the bottom end there is a recess cored or bored out round the valve chest, and communicating all round with the steam passage, as shown in Fig. 7; but at the top end the recess is bridged over on two sides, with passages behind the bridges, as shown in Figs. 5 and 6. The valve rod F has two collars upon it at the top end, and corresponding collars at the other end. The valve G at each end consists of a cylinder with internal flanges and slit longitudinally down the middle: the two halves are planed to a true surface, and afterwards held together while the exterior is turned to a good fit into the valve chest; the internal flanges are then put in between the collars of the valve spindle F, the rod being made square between the collars at each end, and the internal flanges made to fit it. The bottom end of the valve rod F descends through a stuffing box, and

is keyed into a rod with two collars for the forked valve lever H to work it up and down; while at the same time it may be turned partly round by means of the short lever I, the lower part of the rod being made square and working through a square eye in the lever I, which is connected with a hand lever worked by the attendant. The lower cylindrical valve G is perforated all round, as shown in Fig. 7; but the upper one only on two sides, as in Figs. 5 and 6; consequently, whilst the valve is being worked up and down, it can be turned partly round in the valve chest, so as to prevent any steam from entering the upper end of the cylinder, by the openings of the upper valve being thus made to come opposite the two bridges across the port, as in Figs. 4 and 5; or it can be so adjusted by the hand lever as to admit full steam equally above as below the piston, as in Figs. 2 and 6, or in any degree between these two extremes. The exhaust is at each end of the valve, which is to a very great extent in equilibrium, and has but little friction. The steam is admitted at the centre, the admission being regulated by a cylindrical throttle valve J, Figs. 3 and 11.

The valve gearing for working the valve up and down is shown in Figs. 8 and 9, Plate 140, which represent the two positions when the hammer is at the bottom and top of its stroke; Fig. 10 shows a plan of the gearing. KK are two weighshafts with right-angled levers LL upon each, and they are connected to each other by links M, so that when one weighshaft is moved the other moves simultaneously with it. Upon the links M are sliding wedges N, and immediately behind the links are stationary bars O fixed to the framing of the hammer, with sliding boxes P connected to the wedges N by links R of the same length as the levers L. The sliding boxes P are connected to the two hand levers S, and the attendant can instantly move them and thereby adjust the wedges N into any position upon their respective links. Upon the hammer block D are fixed two rollers T, one behind the other; when the hammer block rises, the front roller acts upon the upper wedge N and pushes it aside, while at the same time the lower wedge is advanced by means of the right-angled levers L; when the hammer block falls, the back roller acts in the same manner upon the lower wedge. The forked lever H for working the valve G is fixed on the upper weighshaft K.

The lower sliding wedge N can be adjusted so that the valve shall be moved simultaneously with the blow given, and the steam admitted

below the piston for the return stroke; or it can be raised so that the roller shall come in contact with it before the blow is given, in which case the steam is admitted before the blow is given and forms a cushion to check the momentum and soften the blow; or the wedge can be raised still higher and the steam admitted so as to pick the hammer up again before it can reach the object it was intended to work upon. As the two wedges N can be instantly brought near to each other on any part of the links M, or as instantly separated to the greatest distance apart, so can the length of stroke be made very short near to the anvil or upon any thick object the hammer has to work upon; and when a heavy forging is upon the anvil, requiring from its great mass of material heavy blows to take sensible effect, although the stroke is short the required speed is given to the hammer by the steam upon the top of the piston, and the effect obtained is greater than with the longest range hammers hitherto brought into practice, on account of their being only single-acting. Not only is the blow very great but a great number of blows can be given in a very short time; the hammer can thus be worked very fast or very slow, or single blows can be given at any desired intervals of time, and regulated in effect to the greatest nicety.

A small hammer on this principle has been designed for rivetting, and is expected by Mr. Naylor to prove of great advantage in the present extensive application of wrought iron plates in the construction of bridges and ships, where heavy thick plates and large rivets have to be used, requiring the rapidity of stroke of hand rivetting combined with a much greater force of blow than can be given by hand, in order to get the rivets hammered down while retaining sufficient heat to prevent the fibres of the iron becoming crystallised under the action of the hammers. In these cases such a great amount of power is required that the strength of men is unequal to the work; and as this steam rivetting hammer can be made very light, the speed being merely a question of relative force and weight can be increased to any desired extent. One of these hammers will strike nearly as quick as two experienced men can with their light hammers; and when the hole in the plate is well filled by the rivet under light blows, so as not to blur it up between the two plates, then blows can be given heavier than men could give with sledge hammers. In machine-rivetted boilers the rivets are driven into their place by the

action of steam upon a piston, either direct or conveyed through a lever, the rivet being compressed by one ponderous crush; but a direct-acting hammer, giving a number of very quick blows followed by a few heavy ones to finish the rivet, has all the advantages of hand rivetting, whilst leaving the rivet hot and not crystallised by cold hammering. By using flexible steam pipes this rivetting hammer can be suspended to any object and worked in any position. For ship building the hammer can be suspended from a bar outside the vessel, and a heavy dolly from a bar inside, the latter being guided and held by a man; the hammer whilst working being kept up to the ship's side by a pin and cotter through the hole preceding the one being filled by the rivet. The back part of the hammer is capable of having a rotatory motion given to it whilst hammering at full speed, and consequently the head of the rivet can be met at any angle and laid into the countersunk hole in the plate with greater accuracy than can be done by the most experienced workmen with hand rivetting hammers.

The advantages of the double-acting steam hammer for forging are that it can not only be worked as a single acting hammer at any time, but the power can also be more than doubled instantaneously and as rapidly removed; the adjustable valve gearing also allows of instantly changing the length of stroke and force of blow, by altering the position of the sliding wedges; and this hammer can perform a much greater quantity of work in a given time than any other hitherto in use. A great advantage is also derived from the valve being in equilibrium, requiring consequently much less force to move it than the ordinary valve; and the strain and wear upon the valve gear is by this means reduced to a very small amount. The freedom of motion of the valve allows it to be opened and shut almost instantaneously, thereby affording a more free and rapid exhaust than can be obtained with the ordinary valve; this is further aided by the form of the port, which extends all round the outer circumference of the valve. In the manufacture of iron under the hammer the maximum effect of blow must be sufficiently powerful to crush and flatten the entire mass of the bar from its outer surface to the centre; for unless the blow be sufficiently powerful to penetrate through to the centre of the mass, the bar cannot be properly worked, drawn out, and elongated; hence a great advantage experienced is that by admitting

steam at the top of the piston the power of the hammer can be more than doubled, and the force applied will then be sufficiently powerful to obtain the necessary result.

In the construction of this hammer it must be borne in mind that the strength of the frame and foundations must be proportioned to the power obtained, and will therefore be required proportionately greater than in a single-acting hammer of the same size, since every part must be in proportion to the maximum effective blow.

The CHAIRMAN observed there could be no question as to the importance of the subject of the paper; amongst the numerous inventions of every description brought forward at the present day for meeting the increasing demands of work to be executed, probably none had proved more valuable than the steam hammer, or had been so extensively brought into use. There were still however many difficulties and prejudices to be overcome that limited its employment; and any improvements increasing the range and convenience of its application formed important subjects for discussion. It was remarkable that whilst steam hammers had been largely introduced in other parts of the country, in Staffordshire their use was very limited at present; and it was a question well worth enquiring into, what was the reason for this difference. Some of the points of objection would probably be met by the construction of the hammer now described, which might tend to a removal of the difficulties in the way of the more general adoption of the steam hammer. He enquired what was the largest sized hammer at present constructed on that principle.

Mr. MARKHAM replied that the 25 cwt. hammer described in the paper was the largest yet made on the plan; there were three other smaller hammers at work on the Eastern Counties Railway. The large one was an ordinary steam hammer that had been altered for trial, and the result had proved so satisfactory that Mr. Eastwood was making a new one of the same weight, which would soon be completed.

Mr. EASTWOOD said the steam hammer at his works had certainly answered very well; it obtained the greatest speed and hit to the greatest nicety of any steam hammer he had ever worked, as it was completely under control by the hand gear, which was easy to work, or hold in any position. The rapidity of stroke obtained by

it was particularly advantageous in the case of forgings requiring a great number of blows, by finishing the work at one heat, saving both the fuel required for the second heat, and the deterioration and waste of the iron.

The Chairman asked whether the application of the principle to heavy hammers of 4 or 5 tons weight was considered advisable.

Mr. Eastwood said from his experience he would recommend it more particularly for light than heavy hammers, as with a heavy hammer quick blows were not so much wanted, and sufficient force of blow was already obtained in such cases by the weight of the hammer alone.

Mr. Naylor said the plan had not been tried yet for a heavier hammer than the 25 cwt. one; but he had arranged a hammer up to 5 tons weight on the same principle, and expected the advantage of quicker blows obtained by it would prove an important gain in several kinds of work. He had also made a modification in the construction, whereby the jar caused in the cylinder by the side shake of the piston when the blow was struck was prevented, by prolonging the piston rod above the piston to work in a blank pipe at the top of the cylinder. In consequence of the slide valve being so nearly in equilibrium, a very slight force was sufficient to work it, and the catches to hold the levers were not needed in practice, the handles being easily held in any position and ready for instantaneously changing the force and rapidity of blow. The valve being put together in two halves between collars on the valve rod was securely fixed, so that without actual breakage of the rod it could not become disconnected. By the turning of the valve partly round, the hammer was worked either double-acting or single-acting, according as the steam was admitted to the top of the piston or excluded from it; the valve was readily turned round whilst working, as the squared part of the rod passed freely through the eye of the turning lever, allowing the steam to be instantly turned on to the top of the piston to any desired extent; and the sudden action of the high pressure steam gave an impulse to the hammer something like the action in a steam gun.

He thought a great advantage would arise from the application of this plan of steam hammer to rivetting heavy work, as the rivets now used were necessarily small in proportion in order to allow of rivetting by hand; an ordinary $\frac{1}{2}$ inch plate was rivetted with $\frac{3}{4}$ inch rivets, but in the case of $1\frac{1}{2}$ inch bars or slabs only 1

inch rivets could be used at present, instead of being increased in proportion to the thickness of the work. The increased requirements of the present time in wrought iron work called for such heavy rivetting that steam power seemed to be needed to meet the case.

The CHAIRMAN asked what was the greatest speed at which the hammer had been worked.

Mr. NAYLOR replied that from 240 to 250 blows per minute had been obtained with the smaller hammers at the Eastern Counties Railway Works at Norwich, weighing 9 cwt.; and the men found it advantageous to work the hammer at the high speed, from the increased facility and convenience given in the work. The range of power of the hammer was much increased by its being double-acting, and this gave a great advantage in forging, for after getting the iron welded up into the required solid state by light and quick blows, it could be followed up instantly with heavier blows to shape the work while the iron was hot and often finish it at one heat. By means of the lower of the two projecting wedges, which was struck by the hammer block in its descent, the steam could be admitted to the underside of the piston at the moment of the blow, or a little before, and the hammer was by that means picked up instantly after the blow, preventing the shake or jar on the anvil and framework which was caused in ordinary hammers from the hammer resting on the work after the blow, the steam not being admitted till after the blow was struck with the ordinary valve gear.

The CHAIRMAN thought the hammer was well deserving of notice, and was glad it had been brought before the meeting. He proposed a vote of thanks to Mr. Markham and Mr. Naylor, which was passed.

The following Paper, by Mr. James Kitson, of Leeds, was then read:—

ON LIGHTING RAILWAY TRAINS WITH GAS, WITH DESCRIPTION OF MR. T. J. THOMPSON'S SYSTEM.

The lighting of railway trains seems to be a subject which has received comparatively little attention during the progress and improvements in the railway system, the oil lamp in present use having undergone but few improvements, though it has been felt to have many defects, the efficiency of the light being counteracted to a great extent by the construction of the lamp, and its position causing a small proportion only of the light to be of service in the carriage. Gas possesses important advantages over all the oil lamp arrangements yet produced, in the constant brilliancy of the light, requiring only two lights for each carriage—the saving that may be effected by turning off lights from all unoccupied carriages—the brilliant light thereby obtained for the tail and side lights of the train—and the saving in expense.

The first use of gas to the writer's knowledge for lighting railway trains was in the United States, where an arrangement which seemed to answer was tried during 1856 upon the Galena and Chicago Railway. Under the floor of each car is placed a gasholder, consisting of two tubes, each divided into two compartments by a longitudinal diaphragm of india rubber. Gas is admitted to the tube on one side of the diaphragm from the gas main at the station, thereby pressing the diaphragm against the side of the tube; and the gas is then forced out to the burners by means of a dry meter or small pump, placed on the car, which pumps in air on the other side of the diaphragm, pressing it back against the opposite side of the tube, and thus forcing out the gas. This arrangement has many advantages for an American railway, where a railway car is so much longer than an English carriage, one car accommodating about 70 passengers, and the number of cars therefore required to form a train sufficient to carry 200 passengers amounting to only 3, whereas upon an English line it would require 11 carriages to accommodate the same number of passengers. The advantage of the American system of railways for adapting a gasholder to each car independently is very great, each car being carried upon two trucks which have their bearings close to the ends of the car, thereby leaving a large unoccupied space 20 or 30 feet

long, which is well adapted for a gasholder sufficient to supply 6 lights for 12 hours: and as three cars would form an ordinary train, the trouble of filling three gasholders once in 24 hours is therefore trifling where 200 passengers can be accommodated.

The success of these experiments induced Mr. T. J. Thompson to endeavour to produce an arrangement for the use of gas lights, which would be suitable to the English principle of railway trains. From the difference between the two systems of working, an arrangement that would answer upon an American railway would be inapplicable in this country: to have a gasholder as above described under every carriage, where a company may have 400 or 500 carriages, would involve an expenditure which could scarcely be repaid by any result; whilst the great difficulty of keeping such a stock of gasholders in perfect repair, and the annoyance arising from the slightest defect, would prove a constant source of complaint from travellers. The difficulty of finding a small defect in a gasholder in such a confined position as it must occupy under an English carriage, and the expense of keeping a large number in perfect repair, would involve the necessity of keeping a staff of men for that department alone. The labour of filling the gasholders would cause much loss of time and waste of gas, in coupling and uncoupling pipes, &c.; and to fill them in an expeditious manner a greater pressure must be obtained than that of the town, which is only from 2 to 3 inches of water; but any attempt to expedite the filling by suction of the gas from the pipes would have the effect of extinguishing all the lights upon that line of pipe, and drawing air into the pipes. When carriages or trains are shunted into a siding or shed to lie by for days or weeks, the gasholders under each carriage being full or partially so would remain with their charge of gas until again brought out, and would require to be tight to an extraordinary degree in order to hold gas for that length of time; otherwise the quantity of gas lost in this manner upon an extensive railway would at the end of a year amount to a considerable sum.

In order to obviate the above objections and defects, and to produce an arrangement suitable for an English railway, two requisites have to be obtained:—first, a gasholder suitable to supply a train of carriages, and formed of a material not perishable; and secondly, a perfect form of coupling, with which the escape of gas from neglect or carelessness in putting together a train of carriages is impossible.

A gasholder forming a separate piece of rolling stock by itself would not be practicable, excepting in cases of very long trains, since the expense of haulage would to a great extent counteract the advantage gained by adopting gas in place of oil; and it is therefore necessary that it should form part of the tender or luggage van, or be combined with some other portion of the existing rolling stock. A rectangular gasholder upon the ordinary stationary principle, 10 feet long, 7 feet wide. and 3 feet 6 inches deep, would require a mass of water weighing about $6\frac{3}{4}$ tons, a dead weight which would be inadmissible for running over a line; and the motion of such a quantity of water would render it difficult to get a gasholder to work properly, while the balancing of the gasholder by weights would also be a complicated arrangement.

These objections have been overcome by the use of a simple form of gasholder, which can be adapted to the tender or the luggage van, or can be combined with any of the carriages.

Figs. 1 and 2, Plate 141, show this gasholder as combined with the tender; Fig. 1 is a longitudinal section showing the gasholder empty, and Fig. 2 a transverse section enlarged showing it full of gas. In place of the horse-shoe form of tank, a rectangular tank A is constructed, having only an aperture 12 inches diameter in the bottom, where the pipe B for filling it with water enters, being brought up for that purpose at the back of the tender, the air escaping through the pipe C while the tank is being filled. The feed valves D are placed at the bottom of the tank, the rods which work them passing through stuffing boxes, to prevent any leakage of water; E is the coke partition. Round the four sides of the tank is an outside sheeting FF, $1\frac{1}{4}$ inch from the sides of the tank, formed of thin wrought iron plates about No. 16 wire gauge thickness, which is fastened round the bottom of the tank to a wrought iron frame G, as shown enlarged in Fig. 13, Plate 143. This gives a space round the tank, $1\frac{1}{4}$ inch in breadth and the depth of the tank, which forms the water space for the gasholder H to work in; the roof of the gasholder when empty being 1 inch above the roof of the tank, as shown in Fig. 1. The outside sheeting F and the sides of the gasholder H are carried up 12 inches higher than the roof of the tank, so as to allow for variation in pressure of the gas. At the four corners of the tank are placed guide rods I, which are fastened into the bottom frame G, as in Fig. 11, and stayed at the top by light wrought iron stays, rivetted to the top of the outside

sheeting F, as in Fig. 1. The guide rods I are placed inside the water space between the outside sheeting and tank; and brass roller guides J, Figs. 11 and 12, are fixed at the top and bottom of each corner of the gasholder, which work upon the guide rods. Round the bottom of the gasholder T iron or angle iron is rivetted to prevent the springing of the plates under the pressure; and at distances of 4 or 5 feet small rollers K, Fig. 13, are placed, so that should the pressure be sufficient to spring the sides of the gasholder these rollers would come in contact with the outside plates F, and prevent the gasholder from catching in any way upon the plates or rivets. In the water spaces round the gasholder and over the top of the tank strips of light angle iron are placed, to act as breakwaters and prevent any oscillating motion being imparted to the water; and a strip of strong leather is fastened round the top of the outside sheeting F, against which the sides of the gasholder work, for the purpose of preventing any pieces of coke from getting into the water space. Through the centre of the water tank passes the gas pipe L, which extends 12 inches above the top of the tank, so as to prevent any water getting into it; and upon the gasholder is a small dome M fitting over the pipe. The pipe L branches off below the tank to each side of the tender NN, where a coupling or union joint is fastened on the ends, for the purpose of coupling on to the pipe of the stationary gasometer. A small gas pipe O branches off from the pipe L to the coupling apparatus at the back of the tender, and so on for the supply of gas to the carriages.

A gasholder such as above described, 10 feet long, 7 feet wide, and 3 feet 6 inches deep, will contain 216 cubic feet of gas, allowing the bottom of the gasholder to be 5 inches below the level of the water when full of gas, as shown in Fig. 2, which is a necessary allowance for motion of the water or the difference of level of the two ends caused by steep gradients. The consumption of an average sized burner being 3 cubic feet per hour, a train of 12 carriages burning 2 lights each gives 24 lights consuming 3 cubic feet per hour each, or 72 cubic feet total, making a consumption of 216 cubic feet in 3 hours; so that this gasholder will supply 12 carriages for 3 hours. The process of filling the gasholder is simple. At the principal stations along a line, at distances of from 50 to 100 miles as circumstances may admit, there are small supply gasometers, from 8 to 12 feet diameter, which work at a pressure of from 12 to 24 inches of water. When a tender gasholder requires filling,

the pipe N is coupled by means of a union joint to the supply gasometer: and the pressure being from 8 to 20 inches greater in the gasometer than in the tender gasholder raises the latter and fills it in from 1 to 2 minutes. The level of the water in the tender gasholder is 1 inch above the roof of the tank, as shown in Fig. 2; so that, when the extra pressure is admitted to the gasholder by connecting it with the supply gasometer, the additional height of water required between the outside sheeting and the sides of the gasholder is supplied with a difference of only about $\frac{1}{4}$ inch in the level of the water on the roof of the tank. As it was anticipated that the motion of the train would have the effect of giving the gasholder a jumping motion between its guides, owing to the elastic character of the gas, it was thought necessary to guard against this by inserting a rack in each guide rod and fixing a spring catch upon the top corners of the gasholder, which, after catching the teeth of the rack, prevented the gasholder from rising. However, in making practical experiments with the gasholder this provision proved to be useless, the gasholder working comparatively steadily, and having no tendency to rise more than $\frac{1}{8}$ inch. The result of this slight motion upon the flame was evident, in some instances drawing the gas back from the burner and consequently extinguishing the light. These shocks, which are instantaneous, are now remedied by the simple arrangement of placing a small back flap valve at the junction of the pipe O with the gasholder, which remains open so long as the gas enters the pipe from the gasholder, but closes whenever the gasholder has a tendency to draw the gas back from the pipe. The working of the valve has but a very slight effect upon the pressure in the pipes, the action being so rapid; and the effect upon the flame could not be detected when this plan was adopted.

The gasholder as combined with the luggage and guard's van is similar in principle. Fig. 3, Plate 142, shows a longitudinal section of the gasholder, with side elevation of the luggage van; the gasholder is 15 feet long, and the luggage van 8 feet long, making a total length of 23 feet, running upon four wheels. The interior space might perhaps be made available for carrying luggage, by means of a door through the bottom, the construction of the gasholder rendering a door impracticable in any other place. L is the pipe for filling the gasholder, from which the small gas pipe O for supplying the carriages branches off, having a few holes or burners in order to prevent the water from freezing in severe weather

during the time a train may be stationary, the quantity of water being so small that two or three lights would be sufficient for this purpose. The gasholder contains 395 cubic feet of gas, capable of supplying 30 lights burning for 4 hours. When empty it would be 4 feet 6 inches in height from the top of the frame G to the top of the outside sheeting F, in that position offering but a small surface to be acted upon by the wind; when perfectly full, from the level of the rail to the top of the gasholder would be 11 feet: the average height from the rails to the crown of the roof of a first class carriage being 10 feet, a horse box 11 feet, and guard's van 11 feet 6 inches, the gasholder when full would therefore not expose a greater surface for the wind to act upon than the other portions of the rolling stock. There is an advantage in adapting the gasholder to the guard's van at the present time, even supposing the interior could not be made available for luggage, from the impracticability of altering the tenders made upon the present system, and from the guard's van for a passenger train not being in many instances of sufficient weight in itself as a break van, and requiring the addition of a considerable weight of iron to make an efficient break; in place of which dead weight the gasholder will give all this advantage, the weight of a gasholder 10 feet long being about $1\frac{1}{2}$ tons, including the water requisite for its working. Also when running at the end of the train, the tail light C, which is the most important, will be upon the same carriage as the gasholder, and supplied by an independent pipe, which will preclude the possibility of its going out of order.

The satisfactory working of the above arrangement of gasholder has been practically ascertained by trial upon different lines, where it has been severely tested by being placed upon uneasy working trucks, which were found to have no effect upon its working.

A supply gasometer was then required for charging the train gasholders, of simple construction and small expense, constructed on a principle which would render escape or waste impossible.

The supply gasometer shown in Fig 4, Plate 142, is a small circular gasometer A, 12 feet diameter and 8 feet high, containing about 900 cubic feet of gas, sufficient to supply 2 or 3 train gasholders without being filled from the gas works. It is balanced with weights running over pulleys in the ordinary manner. As the pressure requisite for filling the train gasholders is from 12 to 24 inches of water, and the ordinary pressure at gas works only from 2

to 3 inches, the extra pressure in the gasometer is obtained by water on the roof B. In order to fill the gasometer with gas, the water is all run off the roof B by opening the cock C, and the gasometer being balanced by weights rises with the gas works pressure, the gas being admitted by the pipe D, through a self-acting gas valve E. As the gasometer rises the lever of the cock C comes in contact with the projecting catch F, which shuts the cock C; and the gasometer rising to the top of its guides, the projection I comes in contact with the lever G, and opens the water valve H, letting water on to the roof B of the gasometer through the pipe K. When sufficient water has been let on the roof to give the required pressure, the gas is compressed by the gasometer falling a certain distance, and the projection J depressing the lever G shuts the water valve H; the gasometer is then ready to supply the train gasholders with gas. The working pressure of the gasometer can be regulated at pleasure, by merely moving the catch J lower or higher upon the side of the gasometer, which will shut the water valve H sooner or later, according to the degree of pressure required. The water on the roof of the gasometer is prevented from freezing by the gas burners L, from which the heated air passes through the pipe M and is distributed over the surface of the water, the tank B on the roof being covered over, with only an aperture where the water pipe K enters. A small hole is left at the bottom of the pipe K, through which the water gradually runs off when the valve H is shut, preventing the pipe from being frozen up.

The self-acting gas valve E, shown enlarged in Figs. 5 and 6, rises and falls with the slightest difference of pressure between the gas in the gasometer and that in the gas works pipe. The longitudinal section, Fig. 5, represents the valve when the pressure in the gasometer is 12 inches of water. The seating of the valve is formed of two circular ribs N and O, cast round the entrance of the pipe P into the box, the distance between them being about $\frac{1}{4}$ inch, leaving a space similar to the water space round the gasholder, which is filled with mercury $\frac{3}{4}$ inch in depth. The outside rib O is carried up above the height required for the mercury, to serve as a guide for the valve to work in. The valve R is formed of thin sheet iron, and is balanced by a weight at the opposite end of the beam S, which works upon a fine fulcrum. When the pressure is equal above and below the valve, it merely touches the surface of the mercury; but

when the water is let on to the top of the gasometer, the pressure in the gasometer sinks the valve, and causes the mercury to rise according to the pressure. This form of valve is self-acting in every respect and must be perfectly tight, no leakage being possible, the only communication being through the mercury when the valve is down.

The coupling between the carriages is effected by vulcanized india rubber tubing, with a cut-off apparatus fastened upon each end of every carriage.

The coupling apparatus is shown in Figs. 7 and 8, Plate 143. It consists of a short cut-off pipe A, working upon a stopper B similar to an ordinary cock; the india rubber tube is attached to the pipe A by a union joint C. When the cut-off pipe A is down against the side of the carriage, as in Fig. 7, the hole in the pipe A coincides with that in the stopper B, leaving a clear passage for the gas: in this position the pipe A is held by a spring D, which clasps it close above the union joint C; and the joint C is protected and closed in by the two projecting wings EE. In uncoupling the carriages, before disengaging them the porter pulls the india rubber tube, and thereby raises the cut-off pipe A into the position shown dotted in Fig. 7; in this position the gas is cut off, and the pipe A is held by the spring catch F, which prevents it from falling back, enabling the porter to unscrew the union joint C. The india rubber tube is attached to the carriage by a chain, and when disconnected is hung upon a hook on the carriage, a tube being provided at each end of every carriage. In coupling together the carriages, after the carriage coupling has been screwed up, the india rubber tube is attached to the cut-off pipe A by the union joint C, which requires three turns, and the pipe A is then released from the spring catch F and pushed down between the projections E, thus turning on the gas to the carriage. The whole time taken up in either case should not exceed a quarter of a minute. In the event of one carriage becoming accidentally detached from the next, in consequence of breakage of the carriage coupling or otherwise, the strain thrown upon the india rubber tube will pull the cut-off pipe A into the horizontal position before the tube breaks, thereby cutting off the gas; and this coupling accordingly prevents any possibility of a carriage being detached from a train without cutting off the communication with the gasholder.

The pipe supplying the burners in each carriage may run under the floor or along the roof, as is most convenient. When a carriage is detached from the gasholder, as in shunting at junctions, the lights in the carriage are prevented from going out by means of a small india rubber supply bag, about the size of an ordinary air pillow, which is placed under one of the seats of the carriage, and connected to the gas pipe supplying the burners. When the pressure of gas in the pipe is reduced to 1 inch of water, the supply bag begins to collapse, supplying the burners until the carriage is again attached to a train; the bag containing about 1 cubic foot of gas, which would be sufficient to keep the two burners in each carriage supplied for about half an hour; for supposing the two burners consume 3 cubic feet each per hour at the gasholder pressure, they will with 1 inch pressure of the supply bag burn about one third that quantity, and 1 cubic foot will consequently last for half an hour.

Fig. 9, Plate 143, shows the position of the coupling apparatus and connecting pipe when the carriages are coupled together, the apparatus being placed in the centre line of the carriage immediately above the carriage coupling hook. The average distance from the end of a carriage to the face of the buffer is 2 feet; and consequently the space between two carriages will be 3 feet 9 inches when the coupling is screwed up 3 inches tight, and 4 feet 3 inches when each draw spring is subjected to the extreme draw of 3 inches. A coupling pipe 5 feet long, as shown in Fig. 9, will therefore allow a space of 9 inches between the buffers before a strain comes upon the connecting pipe to draw out the cut-off pipe and shut off the gas. The cut-off apparatus is 5 feet 6 inches from the level of the rails, and the flexible pipe will thus swing from 3 to 6 inches clear of the carriage screw coupling; this is the position that offers the least liability to any doubling of the pipe. The versedsine of a curve formed by a pipe 5 feet long, when its ends are at a distance of 4 feet apart, is $15\frac{1}{2}$ inches; when 5 feet 6 inches long and the ends 4 feet apart, it is 20 inches. The pipe may easily be prevented from swinging closer than 3 inches to the carriage coupling when the buffers are compressed, so as not to catch in any way, as that would cut off the gas when the hauling strain was again imparted to the train.

Fig. 10, Plate 143, is a longitudinal section of a railway carriage through a partition, showing the arrangement for lighting with gas. The burner A, surrounded by a ground glass shade B, is lowered to about

9 inches from the roof, instead of only between 2 and 3 inches as in the oil lamps; and a reflector C is placed above it at a proper inclination to reflect the light that would otherwise be lost through the aperture in the roof. A space of about $1\frac{1}{4}$ inch is left between the reflector and the glass shade for ventilation, and a slide damper at D affords the means of regulating the current of air at pleasure.

The comparative cost of gas and oil for lighting railway trains remains now to be considered.

The actual cost of lighting a train of 12 carriages with oil lamps, while running 100 miles, amounts to about 9*s.* 6*d.*, or 1·14*d.* per train per mile. With 12 carriages burning gas, having 2 lights each, each burner consuming 4 cubic feet of gas per hour, assuming 4 hours as the time taken in running 100 miles, the amount consumed in running 100 miles would be 384 cubic feet; and allowing 5 cubic feet per hour for the tail lamp, and 4 cubic feet per hour for each of the two side lights, making 52 cubic feet in 4 hours, the total consumption would be 436 cubic feet for a train of 12 carriages running 100 miles. Taking the cost of gas at 4*s.* per thousand cubic feet, which is the average cost throughout England, the total cost will amount to 1*s.* 9*d.* in running 100 miles, or 0·21*d.* per train per mile, as compared with 1·14*d.* per train per mile the cost of oil lamps.

If a train of 12 carriages burning gas runs 100 miles per day on an average throughout the year, the cost of gas at the end of the year would be £31 18*s.* 9*d.*, allowing 4 cubic feet of gas per hour to be consumed by each burner, which is 25 per cent. more than should be burned, thus allowing for loss and waste. For the same train burning oil and running on an average 100 miles per day throughout the year as before, the sum would amount at the end of the year to £173 7*s.* 6*d.*, showing a saving in expense during the year for a train of 12 carriages of £141 8*s.* 9*d.* If a railway company run 10 trains of 12 carriages each 100 miles per day on an average throughout the year, the cost of lighting would amount to £1733 when burning oil, and to £319 when burning gas, showing a clear saving with gas of £1414 in the year, after allowing 25 per cent. for leakage or waste. The power of turning off the gas from unoccupied carriages and from trains standing at stations previous to starting and after arriving would at a fair calculation give 15 or 20 per cent. of further saving to be added to the above.

The cost of 10 train gasholders at £30 each would be £300; and assuming a railway company to have 300 miles of road, requiring a small supply gasometer for filling the train gasholders at distances of about 60 miles, 6 gasometers would be necessary in this case at £40 each, making £240 total; and taking the coupling apparatus, pipes, supply bags, and glass shades, at £3 for each carriage, for 120 carriages the cost would be £360. The total cost therefore of fitting up a railway 300 miles long and having 120 carriages, reckoning 10 train gasholders and 6 supply gasometers, would be £900. This taken from £1414 leaves to a railway company, after fitting up their line and carriages complete, a sum of £514 clear, after paying all expenses for the year; and as the outlay for keeping the apparatus in repair would be small, the saving by the use of gas would afterwards amount to about £1400 per annum in the case of 10 trains as above taken.

The comparative cost of lighting railway trains with gas is much more as here taken than would be found in actual practice, since there are so many additional expenses connected with the oil lamp arrangement as at present worked which cannot be ascertained satisfactorily to make the statement of the cost of oil complete.

In working out the above arrangement for accomplishing the desirable object of lighting railway trains with gas, it has been endeavoured to combine simplicity of construction and working with self-acting apparatus wherever practicable.

Mr. Thompson showed a model of the tender gasholder in action, and a specimen of the coupling pipe and cock.

The Chairman observed that the adoption of gas for lighting railway trains was certainly a great desideratum, as the present carriage lights were very imperfect, and it would be a great advantage to be able to read easily in trains; the only question was whether the difficulties of carrying it out were not greater than was anticipated.

Mr. Clift considered the object was a highly desirable one to be attained; but, though he felt confident that gas would ultimately be adopted for lighting railway trains, he thought the difficulties in carrying out the plan proposed were almost insuperable. In that plan he feared the body of water required in the travelling gasholder tank, though much smaller than in the ordinary construction of a gasholder of the same dimensions, would prove a serious objection; for when the gasholder was running on the line, the violent concussions to which every vehicle in the train was exposed would sometimes cause the water to be driven from one end of the tank to the other and forced out of it, uncovering at the moment one edge of the gasholder and allowing the gas to escape, so that all the lights would be put out. Another consequence of the uneven motion of the train would be that the supply pipe from the gasholder to the carriages would soon become filled with water splashing over into it, and the supply of gas would thus be stopped. It was proposed to prevent the water from splashing by means of small breakwaters fixed at short intervals round the sides of the water space; but he did not think these would prove a sufficient security against the sudden jerks of the train.

There were several ingenious contrivances in the plan described in the paper, among which the connecting apparatus for the coupling between the carriages was a very ingenious mode of preventing risk of accident from the men at stations leaving the gas pipes imperfectly secured; it was necessary, where men who were not practical mechanics were employed, not to have any contrivance that was liable to get out of order in their hands, and great credit was due to Mr. Thompson for having got over this difficulty in so simple a manner. He thought that the station gasometer appeared somewhat complicated in construction; and that it would be preferable, instead of letting in water on the top in order to give the increased pressure for filling the trains, to employ the water in the converse manner, having a permanent weight on the top of the gasometer, and using the water as a counter-balance weight in separate tanks; by filling the tanks with water the pressure in the gasometer would be reduced when it required charging again from the gas main, and by this means the objection of the water freezing in cold weather would be obviated. The use of a station gasometer however he considered unnecessary, as a common gas exhauster attached to the main gas pipe supplying the station would fully answer the purpose of charging

the train gasholders at the increased pressure desired, and could be worked either by men or by a small stationary engine.

As to the advantages of substituting gas for oil in lighting railway trains, there could be no question as to the economy of such a change; and he considered the saving as stated in the paper was underrated rather than the contrary.

Mr. THOMPSON explained that in the train gasholder there was only 1 inch of water over the top of the tank, and this could splash only inside the gasholder, without producing any effect upon the water outside in the narrow side spaces, which was the only portion that could have overflowed.

The CHAIRMAN enquired whether any means were provided for preventing the overflow of water over the sides of the tank in oscillations of the train, by covering over the opening with a leather flap or other contrivance.

Mr. THOMPSON replied that in the full sized tank the outside sheeting was carried 12 inches above the level of the water, which was reduced to 9 inches under the full pressure of gas, and the water spaces were only about 1 inch wide outside the gasholder, with several vertical projecting strips of angle iron acting as breakwaters, which would effectually prevent the water from splashing over the edges of the tank. In the model, the height being reduced in proportion left an edge of only 1 inch height above the water, which allowed it easily to flow over at a jerk; but in the travelling gasholder with which the plan had been tried, the spaces between the angle iron breakwaters were 1 inch wide and 3 feet long with 6 inches height of the outside sheeting above the water, and it was found that no water was thrown over by the oscillation of the train, though the gasholder was carried only on a rough truck. He doubted whether it would be practicable to fill the train gasholders by any plan of pumping from the main, as he had found in making experiments upon that plan that it caused the lights to be put out all along the main for some distance.

The CHAIRMAN asked whether any trial of this mode of lighting trains had been made upon a railway.

Mr. THOMPSON replied that the only trial at present made had been to ascertain the practicability of obtaining a steady light from a travelling gasholder; this had been well tested with the experimental gasholder by carrying it on a loosely coupled truck at the end of the train, the gas pipe being connected to the last carriage; and it was found to give a steady light, not impaired by the oscillation of the gasholder truck.

Mr. Chellingworth suggested the construction of a gasholder with flexible sides, like a pair of bellows, as more suitable for carrying in a train than a water gasholder, if a sufficiently durable material could be employed.

Mr. Thompson thought it would be difficult to construct a gasholder in that manner so as to keep it gas tight; he considered the use of water, as in ordinary gasholders, was the best mode of effecting the object.

Mr. Markham thought the quantity of gas calculated to be consumed by each burner was not enough. It had been stated in the paper that 6 cubic feet of gas per hour were sufficient to light each carriage with two lamps; but three lamps in each carriage were now being used on the Midland Railway, and the carriages were being altered for that purpose, as two lights were not found satisfactory. He was of opinion that three lamps would consume 12 cubic feet of gas per hour, instead of 6; the size of the gasholder would therefore have to be double that proposed, and it would then be found extremely inconvenient.

Mr. J. Hodgson Jones believed that the average cost of the gas to be used would have been more correctly calculated at 5*s.* instead of 4*s.* per 1000 cubic feet; and that with the ordinary quality of gas more than 3 cubic feet per hour for each light would be required. The cost of wear and tear of the apparatus did not appear to have been noticed, and he thought with such a gasholder as had been described the wear and tear would be considerable under the rough usage that it would meet with, and would render the use of gas more costly than that of oil. While the train was in motion all the parts of the apparatus would be at work, and would require a considerable outlay for repairs. He did not apprehend that the water in the gasholder tank would be liable to tail up to the end of the water spaces; but he had employed successfully in small gasworks an elastic diaphragm gasholder, and thought that probably one with flexible sides would prove much better for the supply of a train than a water gasholder. He feared some difficulty would be experienced from liability of the lights to go out sometimes, and some means was wanted for adjusting the back flap valve at the entrance of the supply pipe to prevent such an occurrence; there should also be complete provision for shutting off the gas from the carriages in case of accident, to prevent unpleasant smell and danger.

Mr. Cowper did not think there was any convenient place in a train to put so bulky a thing as a gasholder of the size required; if

on the back of the tender just behind the engineman, it would block up his view of the train very much, and the form of the tender would have to be altered, and a rectangular tank adopted instead of the horse-shoe tank. If placed on the guard's van, a large amount of space would be lost, as it was not likely that the vacant space below the gasholder would be made available for luggage, from the difficulty of getting at it from underneath. He did not see how a travelling gasholder could be practically carried in a train, as the motion would interfere so much with its action; and he thought the sides of the tank would have to be much thicker than had been proposed, as they would have to stand rough usage without injury, and should be as strong as the present tender tanks, although it would not be possible to put stays in. Possibly a plan might be found for a dry gasholder in a square flat form on the top of the carriages; but there would be some danger from leakage into the carriages, particularly in case of collision. The relative economy of using gas instead of oil he did not think could prove so great as had been stated, for he had found an ordinary solar lamp cost only $\frac{1}{2}d.$ per hour, and if kept in good order it gave a good light; he thought that more than 3 cubic feet of gas per hour would have to be calculated for each burner in order to light the carriages satisfactorily.

Mr. Clift said a tolerably accurate idea of the consumption of gas in each carriage might be formed, when it was considered that the London street lamps consumed on an average 5 cubic feet per hour; he thought that 3 feet per hour would be sufficient to light a railway carriage well, but the loss from leakage and uncoupling the carriages would increase it to 5 feet per hour.

Mr. Markham did not think it would be found objectionable in practice to place the gasholder on the tender on the ground of obstructing the view of the engineman; for it frequently happened that a van or horsebox was placed immediately behind the tender, which effectually prevented the driver from seeing the train behind; and so long as the gasholder was not wider than the carriages it would not prove an additional obstruction. He suggested that experiments might be made for the purpose of compressing the gas into a smaller space, in order to economise the room required for the gasholder.

Mr. Thompson remarked that the greater illuminating power of gas must be borne in mind, and a single gas burner at 3 feet per hour would be more than equivalent to two ordinary railway lamps. The

provision for shutting off the gas at every carriage would be quite complete and self-acting, the gas being at once shut off when the coupling pipe was broken or pulled in case of accident, the pipe being closed at both ends of the carriage, whilst the lamps would be still kept burning for a considerable time by means of the elastic supply bag. The cost of gas that had been assumed in the calculation was, he thought, quite supported by the price of gas in the principal towns; London being 4*s.* per 1000 cubic feet, Liverpool 4*s.*, Birmingham 4*s.*, Sheffield 3*s.* to 4*s.*, Bolton 3*s.*

The CHAIRMAN considered the price of gas was not the important part of the question, but the main point was the practicability of applying gas for lighting railway trains, as there could be no doubt of its advantage if the practical difficulties were not too great.

Mr. FERNIE thought the proposed plan of carriage for a gasholder could not be practically carried out, and that a water gasholder was not suitable in a train. He enquired whether any acid or other substance was absorbed by water remaining in contact with gas, that would make it injurious if used in the engine boiler.

Mr. CLIFT believed there was not any injurious change produced in the water; there was only a tarry or oily film deposited on the surface with some ammonia. He did not think the proposed application of gas for railway trains could be carried out, as the objections to placing the gasholder in a water tank appeared insuperable; he was persuaded that in practice, even if the water were not thrown over the sides, it would be liable to rise at one end of the tank, and allow the gas to escape at the other end. The superiority of gas however both for light and economy was so decided, that he was sure before long gas would come into use on some plan for lighting railway carriages. Collapsing gasholders had been tried for the purpose; and that plan, combined with some modification of the ingenious apparatus described in the paper for supplying the carriages, appeared, he thought, most likely to prove ultimately successful. He had no doubt the cost would be much less than with oil, and thought it would prove on the whole to be only one-fifth of the present cost.

Mr. THOMPSON observed that an escape of gas in consequence of the water retiring from one end of the gasholder was provided against by having the bottom edge submerged always 6 inches below the level of the top of the water inside the gasholder; and at the same

time the breakwaters would prevent any great motion from being imparted to the water.

Mr. H. Wright observed that a great difficulty in carrying out the proposed mode of lighting trains by gas would be the necessity for having every carriage in a train adapted for it; this was a serious hindrance to the adoption of improvements in carriages on the trunk lines, on account of the stock of so many other lines working upon them and being mixed in the trains. But if the gas could be placed underneath each carriage, as in the American plan, in a collapsing gasholder or otherwise, so that each carriage would be independent in supply, some carriages might then be lighted by gas and others by oil in the same train. He had no doubt as to the advantage of adopting gas for lighting trains, if it could be carried out; but the cost of lighting a room by gas gave no idea of the cost in a train, for with the present oil lamps the cost of wear and tear was very great, probably even greater than the actual cost of the lighting; great breakage of the glasses occurred, and frequent repairs of the lamps were required, from the rough usage they were exposed to at the stations.

Mr. Inshaw thought there would be great difficulty in obtaining a uniform pressure of gas on a railway with a travelling gasholder floating on water, owing to the elasticity of the gas; the gasholder would be in constant agitation, and on a rough road would oscillate so much as to make the pressure very unsteady; it might be even liable sometimes to produce a partial vacuum in the supply pipe by the sudden jumping of the gasholder, instead of a regular pressure of gas, or to allow the gas to escape from the bottom of the gasholder getting uncovered by the water.

The Chairman proposed a vote of thanks to Mr. Thompson, which was passed.

The following Paper, by Mr. Samuel Thornton, of Birmingham, was then read:—

DESCRIPTION OF WATSON'S VENTILATING APPARATUS FOR BUILDINGS, &c.

The ventilating apparatus described in the present paper, patented by Mr. Charles Watson of Halifax, having been found by the writer to be very satisfactory in the result of its working, and to possess some important advantages, he thought the subject would be considered deserving the attention of the meeting.

This plan of ventilation differs from others in admitting the fresh air at the top of the room or space to be ventilated, the vitiated air being also discharged from the top; instead of admitting the fresh air at or near the bottom of the room, as hitherto generally practised and considered desirable. The result of this arrangement is that the fresh air being cooler and consequently heavier than the vitiated air warmed by the persons in the room, sinks gradually and continuously to the bottom of the room, taking the place of the vitiated air which rises and escapes at the discharge opening at the top. The fresh air sinking thus gradually from the top of the room spreads and diffuses itself over the whole space during its descent, and gives a continuous and uniform supply to the persons upon the floor; this arrangement having the advantage of producing the supply by a uniform slow motion of the air, without rapid currents causing objectionable draughts in particular positions. When the air is admitted at the lower part of a room, as in the usual arrangement, it inevitably causes a quantity of the fine dust that settles at the bottom of the room to be raised and mixed with the air; this inconvenience is avoided by admitting the fresh air at the top, and the motion of this air being downwards, it meets first the heads of the persons in the room, where it is required for breathing, avoiding the objection of first meeting and cooling their feet and lower extremities as when admitted at the bottom of the room. A fact that should never be lost sight of in connection with ventilation is that strong draughts or currents of air are not necessarily ventilation; these do as much or more injury to persons than does the bad air. There may be strong draughts and yet not an exchange of air. The great point to be accomplished in ventilation is a thorough change of bad air for good, in any quantity, in any latitude, and at all seasons, without dangerous and perceptible draughts; and this object appears to have been

attained in the plan now described. Heating and ventilating are usually associated together; but Mr. Watson has been led by his extensive practice to the conclusion that they should be kept entirely distinct, each being accomplished by special means independent of the other. No mode of heating interferes with this mode of ventilation. It has been found that the entrance of the fresh air and the discharge of the vitiated air can be both effected at the same part of the ceiling of the room without incurring any disadvantage; and this allows of a very simple apparatus being employed to effect both objects, giving the advantage of simplicity of construction and application, and convenience for regulation of the supply and discharge. A single tube or flue is employed for the purpose, divided throughout into two passages or shafts, one for the descending fresh air, and the other for the ascending vitiated air; this divided tube generally passing through the roof of the building, and forming a direct communication from the ceiling of the apartment to be ventilated to the external atmosphere. It can however be adapted to almost any situation, and has been applied to buildings of many floors or flats, and to the lower and middle stories of lofty factories, where the heat and steam are withdrawn by a modification of the same arrangement, without taking the ventilating tube through the floors above to get through the roof, the tube being taken through the side wall and terminating outside at the required level.

The simplest and most usual form of the ventilator is shown in Fig. 1, Plate 144, shown enlarged in Figs. 2 and 3, in which the ventilator consists of a vertical circular tube A, of a size proportioned to the size and occupation of the room to be ventilated, divided longitudinally into two passages by a continuous partition B extending to the top. The upper end of the tube is surmounted by a cap C extending all round to some depth below the top of the tube, for the purpose of protecting it from rain and from the disturbing action of wind; this is found to prevent all disturbance of the ventilation, whatever be the direction or force of the wind. The central partition of the tube is carried up to join the cap and complete the separation between the two passages or shafts. A regulating valve D is placed at the bottom of each of the passages, both of which are opened and shut simultaneously by a single cord, thus diminishing or increasing at pleasure the area of passage for the air.

It is found in practice that in the arrangement above described there is so strong a tendency to the establishment of the two currents, one descending and the other ascending, from the downward pressure of the cool external air being greater than the upward pressure of the warm internal air, that when two separate passages are thus provided the two currents are at once set up, and a very slight difference between the two passages is sufficient to determine their direction; when once established, the two currents continue regularly and uninterruptedly, the one side of the ventilator becoming permanently heated and the other side cooled by the respective temperatures of the two currents. In order to fix previously which is to be the ascending side, and to prevent any risk of check or reversal of the currents by accidental causes, the ascending side of the ventilator is carried up a little higher within the cap than the other side, as shown in Fig. 2; and this is found fully to effect the desired object.

The action of this ventilator is shown by the accompanying model, consisting of a glass box, representing a room fitted with a ventilating tube at one corner of the ceiling. When the partition in this tube is removed, so as to leave it a simple flue communicating with the external atmosphere, if a lighted taper is placed in the box it soon becomes dim from exhausting the combustible portion of the air in the box, and although there is a free communication with the external air through an open pipe of considerable size, it is seen that the efforts of the fresh air to enter and of the vitiated air to escape by the same passage so completely oppose and interfere with one another, that the result is an insufficient supply of fresh air to maintain the burning of the taper, which at last becomes extinguished. This experiment illustrates the imperfection in the action of simple openings in the ceiling or upper part of a room to produce ventilation.

By then placing two tapers in the box, a short and a tall one, and allowing a small opening for fresh air to enter near them at the bottom, it is found that the flame of the short taper being near this opening gets a sufficient supply of fresh air to maintain it alight, the flame being blown by the draught; but the taller taper being out of the reach of the direct draught does not receive a supply sufficient to keep it burning. This illustrates the common occurrence of persons in different parts of the same room suffering at the same time from the two extremes of want of fresh air and a draught produced by too much air.

But when the model is altered by simply suspending a partition down the centre of the ventilating tube, without any other alteration, two distinct currents of ventilation are at once established, although no difference is made in the length of the passages to determine the current; and the supply of fresh air to the interior of the box now becomes so ample and regular that several tapers can burn continuously in the interior. By adding the cap on the top of the ventilating tube, the action is made still more complete and certain, and corresponds with that of the ventilators in actual use. The direction of the currents and the gradual and equable diffusion of the air over the interior is shown in the model by allowing the smoke of an extinguished taper to be drawn down the descending passage.

The difference in temperature of the two passages is shown by the thermometers to reach 50° Fahr. in a few minutes. As a rise of temperature of 1° expands the air about $\frac{1}{500}$th part, every 5° gives a reduction of weight of $\frac{1}{100}$th part, or a rising power equivalent to 1 per cent. of the weight of the air; and a difference 15°, such as might occur readily in ordinary ventilation, would give a rising or propelling power acting on the air amounting to 3 per cent. of its weight. This difference in the specific gravities of the discharged and the admitted air effectually prevents any mixing taking place at the upper opening of the ventilating tube; and although the vitiated air is discharged into the atmosphere so near the point where the fresh air is taken in, none of the ascending current can enter the descending passage, as there is no other propelling power to move the air in either direction than the difference in specific gravity of the air in the two currents, which causes them to recede from one another and move in opposite directions, effectually preventing them from mixing. A small actual propelling power is amply sufficient to maintain an efficient ventilation, if a proportionately large area of passage be provided; and a slow velocity for the currents of air is of great advantage in ventilation by preventing objectionable draughts, the most efficient action being that of a slow uniform current, independent of all artificial aids, depending only on the difference of temperature which is always present where ventilation is required, from the warming of the air by the breathing of the persons in the room, besides any artificial sources of warming.

By adapting the size of the tube or the number of the ventilators to the number of persons to be accommodated, the number of gas-

lights burning, or other causes necessitating ventilation, a building can be thoroughly ventilated by this plan however crowded it may be, without any person feeling inconvenience from the presence of bad air, heat, or unpleasant effluvium, or from draughts of air at its admission or withdrawal; and this plan of admitting the fresh air at the top of each room is the only effectual means of supplying the very large quantity required in many cases, without involving the objection of draughts. The means of regulating the passage of air both into and out of the rooms is so completely under control in this apparatus, that the amount of ventilation required for a large number of persons in one building can in a few minutes be diminished to the proportion necessary for a small number, so that the temperature of the building may be kept comfortable, whether in cold or hot weather. The action of the ventilator being produced and maintained solely by the disturbance of the equilibrium of temperature and consequent specific gravity of the air, it is continued as long as there remain within the building persons or other causes to produce that disturbance; and the extent of the ventilation becomes at all times proportionate to the demand for it. When the valves of the ventilator are opened, the action commences immediately, the warmed air from the room ascending on one side and the cooler external air descending on the other, the two tubes thus forming a natural syphon, continuously extracting the vitiated air from the room to be ventilated.

To meet particular cases some modifications in the arrangement of the apparatus are made; and the ventilating tube, although wherever practicable made straight and vertical, has been successfully applied in a moderately bent form, as shown in Fig. 4, where it is required to ventilate the lower portion of a lofty building. In this case the tube is made to deviate as little as possible from the straight vertical form, and terminates close to the external wall at from 10 to 20 feet height above the ceiling of the room to be ventilated.

Another modification of the plan is shown in Fig. 5, where several floors of a house are ventilated into a common staircase, upon the top of which is placed one of the vertical ventilators of suitable size; the communications from the several rooms are made by an opening over the door of each, shown enlarged in Figs. 6 and 7, which is divided into two passages by an inclined partition D in the centre, the upper passage taking out the heated air and the lower one admitting the fresh air.

This ventilator has been applied with complete success to a large number of factories of all kinds in various parts of the country, to withdraw the noxious gases generated in the process of manufacture, and the vapour escaping from wool, cotton, leather, and other raw materials, and from washed and bleached goods in drying rooms. When the vapour is withdrawn continuously by this means from these drying rooms, a saving of one third is effected in the time of the process and the fuel consumed; also in the stoves for drying white lead, and the drying lofts for paper. Moreover, what is of equal importance to the manufacturer, certainty is thus ensured as to the hour when the materials and goods will be dried, irrespective of the state of the weather or the season of the year. Perhaps in no buildings is greater annoyance and loss experienced from vapour in winter than in drying houses and bleaching houses; indeed the vapour is so dense there in some months of the year, that the men cannot see each other when standing at only a yard or two distance; and under such circumstances they must do much of their work by guess, where shades of colour have to be distinguished. The men employed in this class of work are found to be much afflicted with rheumatism, and employers are liable to much inconvenience from the absence of the men from illness, in consequence of continued exposure to this damp atmosphere; the material of the buildings is also subjected to premature decay from the same cause. The application of the ventilating apparatus described above has been found thoroughly successful in removing this serious defect, carrying off the vapour continuously, and so completely as to maintain the air in the building constantly clear and sufficiently dry; producing most important advantages in the preservation both of property and health. The Abbey Print Works of Mr. James Kayess at Stratford, and the Silk Works of Messrs. Courtauld at Braintree, may be referred to amongst others, as instances where great advantage has resulted from the application of this plan of ventilation for dye houses.

In large manufacturing towns, the physical degeneration observed in the working population is probably more attributable to their being congregated together in large numbers in factories where the air is unable from its impurity and deficiency of oxygen to sustain the natural action of the human frame, than to any other cause; few of the operations in our manufactories being injuriously laborious or unhealthy. A large number of the improved ventilators have been

applied to factories where hundreds of operatives work in the same room, and have completely effected the desired change: in some cases 5 per cent. of the hands on an average were always off work previously from sickness, and as many as 20 females in a day were carried out ill; but since the application of these ventilators such a state of things has entirely ceased. Two factories in Birmingham, Messrs. James' screw factory, and Mr. B. W. Goode's jewellery factory, where much gas is employed, may be mentioned as cases where these ventilators are applied, and the air is at all times fresh. It may be remarked that in all cases where manufacturers have incurred expense to ventilate their factories, the expense is found to return interest at about thirty per cent. The improved air enables the workmen to do their work sooner and better, and in many factories where inferior hands only could be procured at high wages, superior hands can now be easily procured at the current rate of wages.

Not only are the operatives seriously injured in health by the want of proper ventilation, but the same cause affects also the employers and clerks in their offices, their families in their houses, and children in their schools; and in large public assemblies of all kinds provision against this is particularly important. At Westminster Chapel the improved ventilators have been applied, and were found successful in keeping that large and crowded building cool and fresh during the last hot summer, without any perceptible draught; with a congregation of 1500 persons the temperature was as low in the chapel at the close of the service as it was out of doors in the shade.

An important application of this ventilator has been made to emigrant ships. In one vessel with 400 on board, the whole were kept down between decks for 5 or 6 days during a violent storm, with the hatches fastened down, but without any inconvenience as to ventilation. When applied to ships these ventilators answer also the purpose of deck lights. For large steamers they have been applied with great advantage to cool the engine room and stoke holes, dispensing with the usual air gratings on deck that have to be closed during a storm and heavy rains; these ventilators admit no water during a storm, the firemen are kept cool without dangerous draughts, and by the plentiful supply of pure air the draught of the furnaces is improved. The application to ships freighted with such cargoes as sugar and fruit would permit of the cargoes being discharged in a dry and more valuable condition, in consequence of the constant withdrawal of the heat and moisture

during the voyage; and in ships freighted with cargoes that are liable to spontaneous combustion, the constant discharge of the dangerous gases would prevent serious loss of property and life.

The necessity for efficient ventilation is as great for animals as for human beings, though not so much attended to; the general want of it is a serious source of injury and loss amongst domestic animals. In many stables the horses suffer from diseases caused by the want of proper ventilation to supply them constantly with fresh air without exposing them to injurious draughts, and to remove continuously the ammoniacal exhalations so injurious to their health. The improved ventilators have been applied in a great number of such cases, and have succeeded in keeping the animals comfortably cool in summer and warm in winter, with a complete freedom from the ordinary smells, and an improvement in their health and condition.

In applying these ventilators to dwelling houses and public buildings generally, the form shown in Fig. 2 is the simplest, and is made of different sizes from 2 to 6 feet diameter according to circumstances, one or more being used as may be required. In large factories, drying houses, and similar cases, a long rectangular form of ventilator is sometimes adopted, divided longitudinally into the two compartments; one of that form is in use at a large paper factory, extending to a length of 60 feet along the roof and 2 feet in width. For houses and public buildings the external form of the ventilators can be varied and modified considerably for adaptation to the various styles of architecture as may be desired, without interfering with the principle of action.

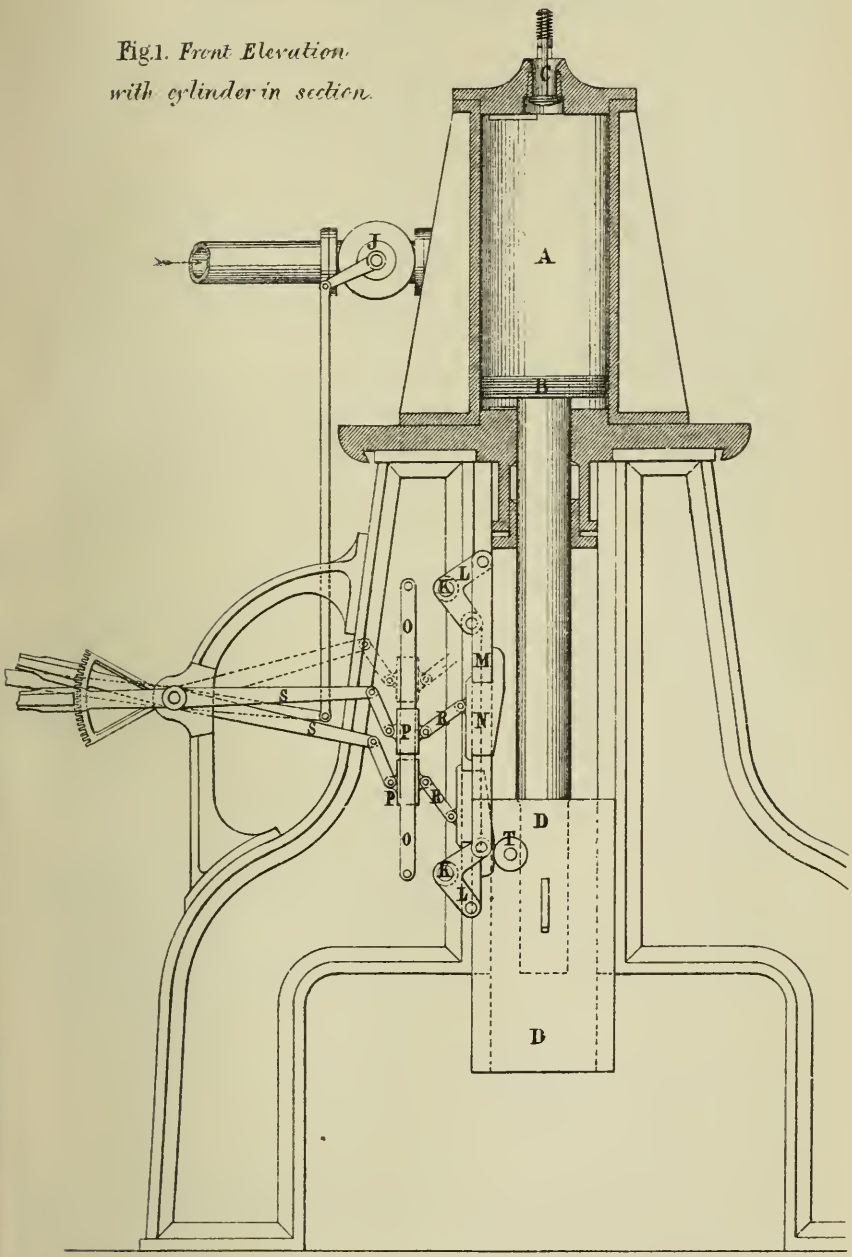
Mr. WATSON showed the model of the ventilating apparatus in action, with the central partition of the ventilator first removed; the candles then burned gradually duller, and when one had gone out from want of air, the central partition was inserted in the ventilator; the two currents of air, one upwards and the other downwards, were then established at once, although both sides of the ventilator were of the same height; and the remaining candles burned brightly again, a difference of temperature being maintained between the two currents of air, amounting to 50° Fahr.

The CHAIRMAN proposed a vote of thanks to Mr. Watson, which was passed.

The Meeting then terminated; and after the meeting a Hydraulic Engine, by Mr. David Joy, of Leeds, was exhibited at work.

. Naylor's Double-Acting Steam Hammer.

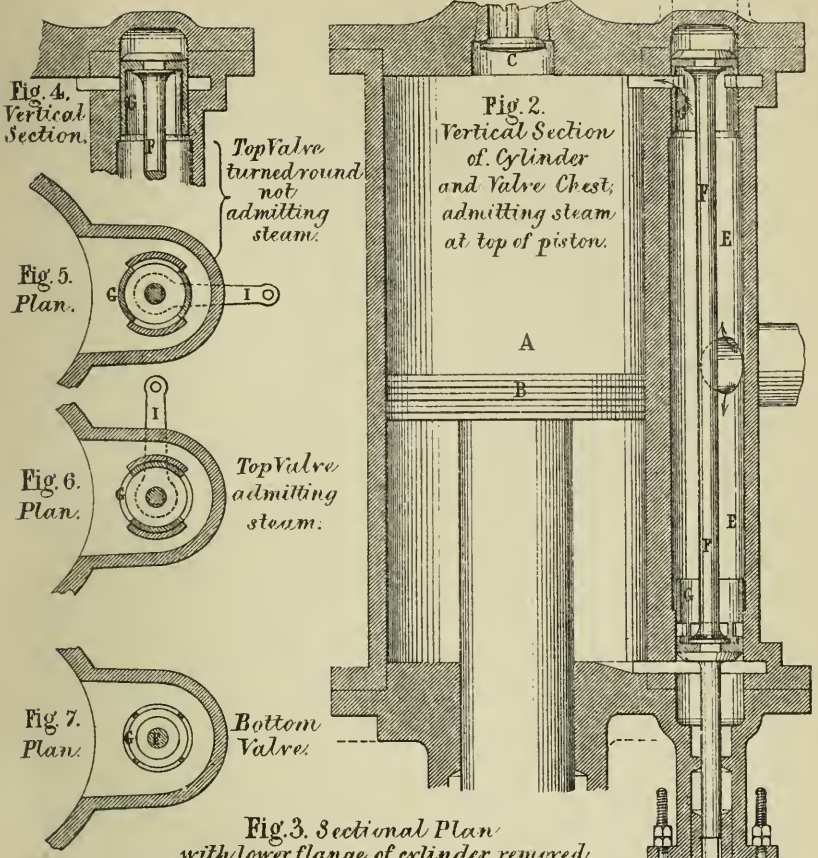
Fig.1. *Front Elevation with cylinder in section.*



Ins. 12 0 0 1 2 3 4 5 Feet.

Scale 1/24th.

(Proceedings Inst. M.E. 1857 Page 235)



(Proceedings Inst. M.E. 1857. Page 235.)

Detail of Valve Gearing and Sliding Wedges.

Fig. 8. *Position at Bottom of Stroke.*

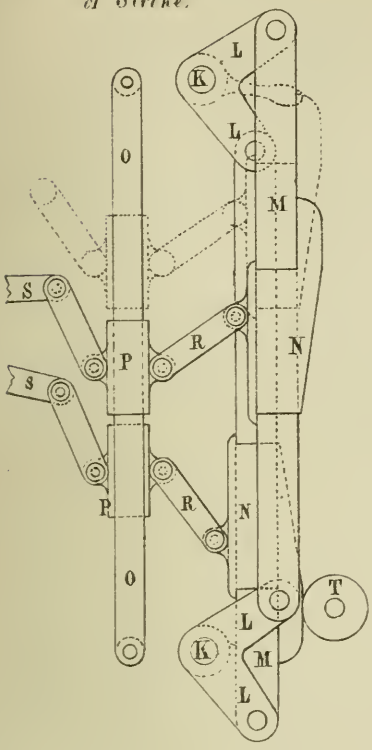


Fig. 9. *Position at Top of Stroke.*

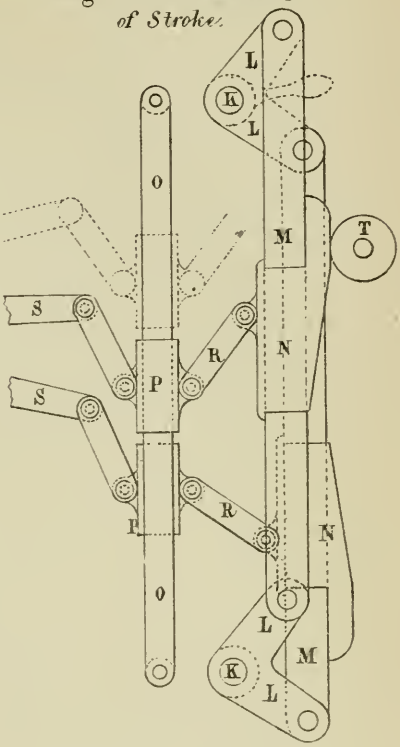


Fig. 10. *Plan of Valve Gearing.*

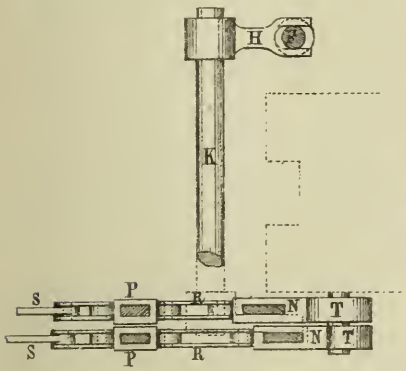
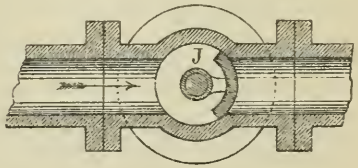


Fig. 11. *Vertical Section of steam throttle valve.*

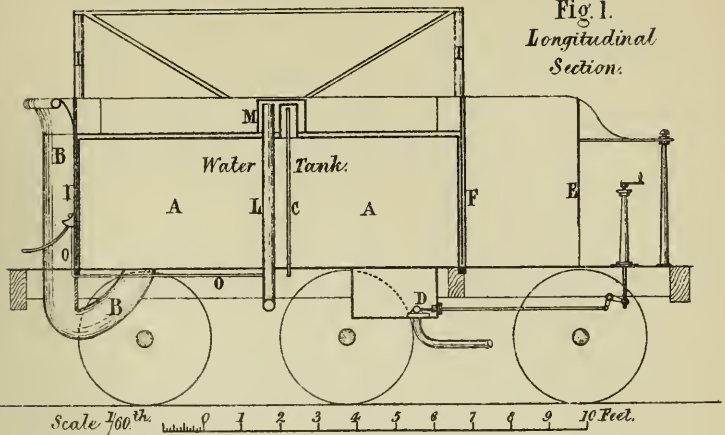


Scale 1/12th. 0 5 10 20 Inches.

(Proceedings Inst. M. E. 1857. Page 236.)

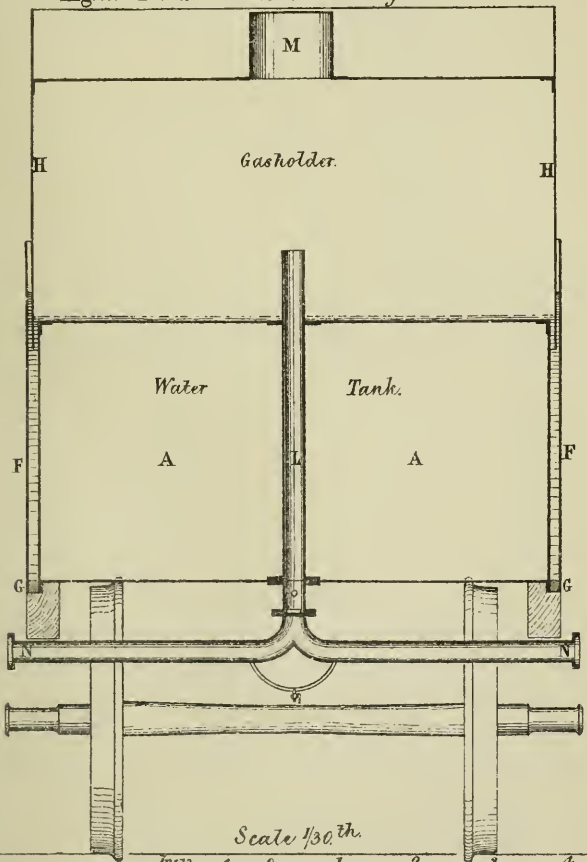
Gasholder combined with Tender.

Fig. 1.
Longitudinal Section.



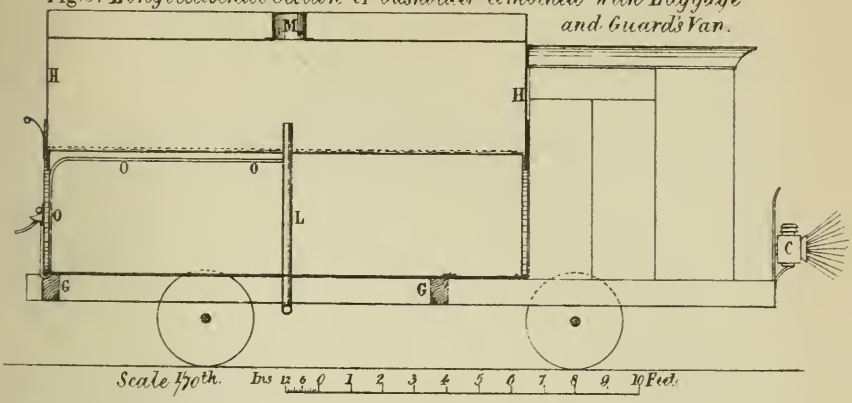
Scale 1/60th. 0 1 2 3 4 5 6 7 8 9 10 Feet.

Fig. 2. *Transverse Section enlarged.*



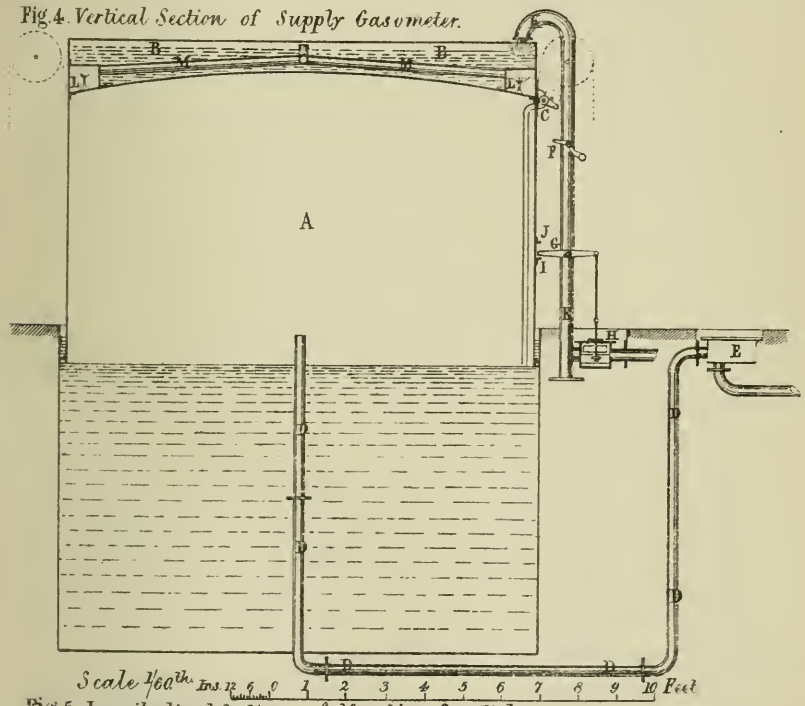
(Proceedings Insl. M. E. 1857. Page 244)

Fig 3. *Longitudinal Section of Gasholder combined with Luggage and Guard's Van.*



Scale 1/70th. Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet.

Fig. 4. *Vertical Section of Supply Gasometer.*



Scale 1/60th. Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

Fig. 5. *Longitudinal Section. Self-acting Gas Valve.*

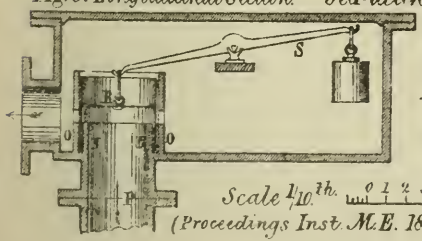


Fig. 6. *Sectional Plan.*

Scale 1/10th. 0 1 2 3 4 5 6 7 8 9 10 20 Inches

(*Proceedings Inst. M.E. 1857. Page 246.*)

Coupling Apparatus between Carriages.

Fig. 7. Longitudinal Section.

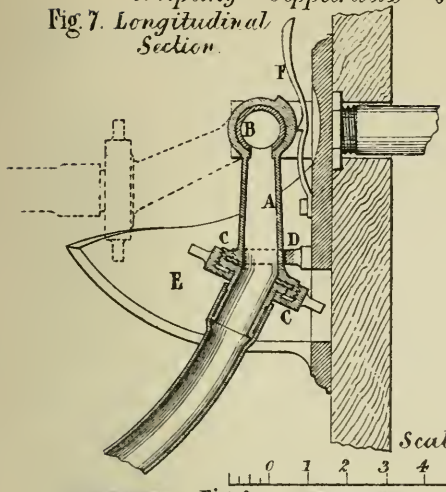
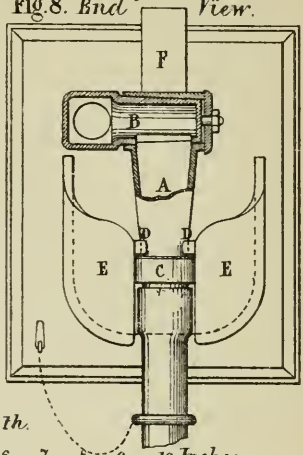


Fig. 8. End View.

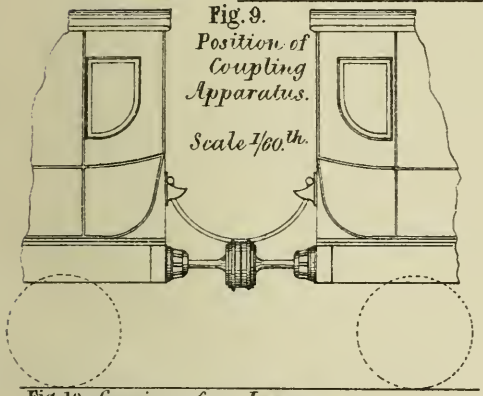


Scale 1/5th.

0 1 2 3 4 5 6 7 8 9 10 Inches.

Fig. 9. Position of Coupling Apparatus.

Scale 1/60th.



Details of Tender Gasholder.

Fig. 11.

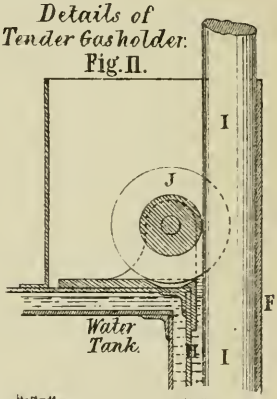
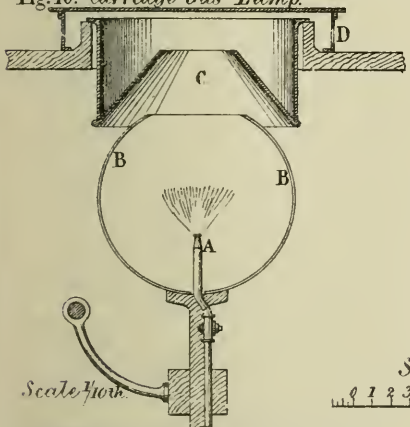


Fig. 10. Carriage Gas Lamp.



Scale 1/10th.

Fig. 13.

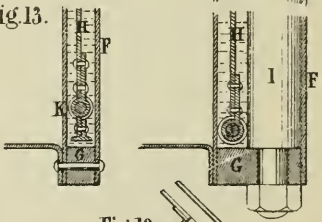
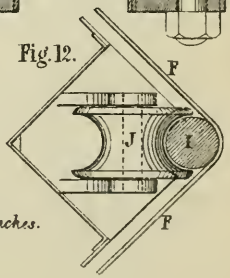


Fig. 12.



Scale 1/10th.

0 1 2 3 4 5 6 7 8 9 10 Inches.

(Proceedings Inst. M.E. 1857. Page 249.)

Fig. 1.

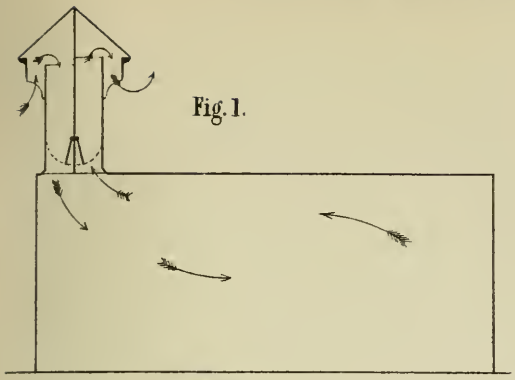


Fig. 5.

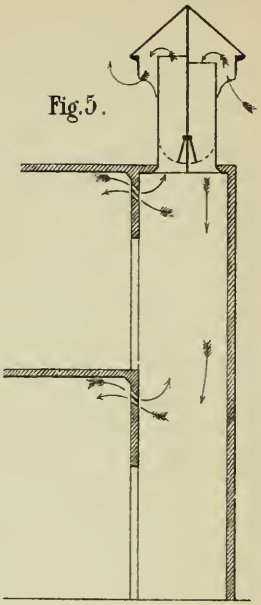


Fig. 2.

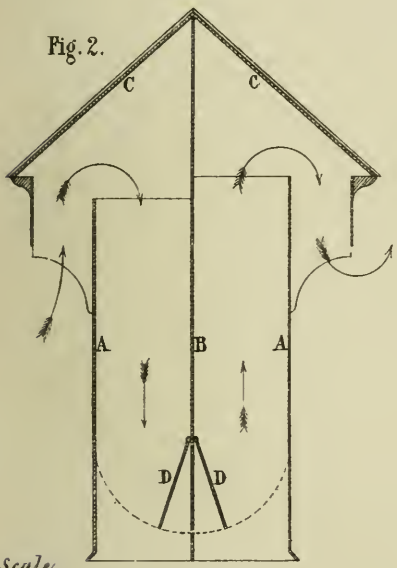


Fig. 4.

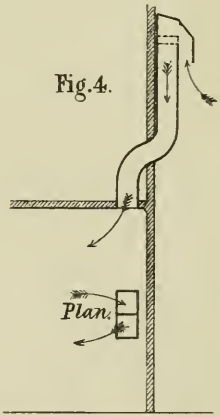


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Fig. 3.

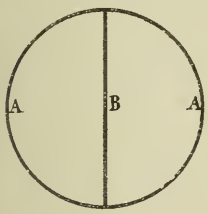


Fig. 6.

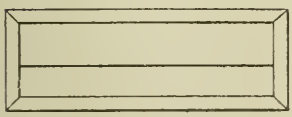
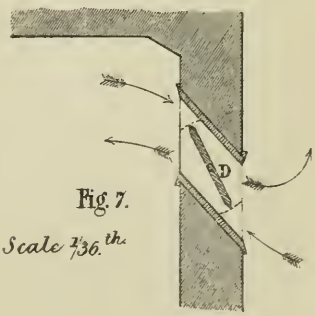


Fig. 7.



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